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CLIMATIC CYCLES AND HUMAN POPULATIONS IN THE GREAT PLAINS[1]

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I

EVERY one is doubtless familiar with the account of a climatic cycle and its effects which appears in the Book of Genesis. The seven fat and the seven lean years suggest that this coincided with the well-known sun-spot cycle, which usually ranges between 10 and 14 years. The seasons of rainfall and drought, of plenty and famine, bear a close resemblance to recent periods of abundance and want. Accordingly, Joseph must receive the credit for issuing the first known long-range forecasts of rainfall and drought. He also achieved a world's record for verification, which has not even yet been equalled in these modern times. Moreover, he was not only the first to propose but also the first to operate successfully an ever-normal granary. Another cycle —or rather, another expression of the same one—was mentioned by Bacon at the beginning of the seventeenth century, when he said that every 5 and 30 years in the Low Countries the same kind of weather is reported to come about again, such as great wet, great droughts, great frosts and warm winters, and that in computing backward he found some concurrence.

More than two centuries later, the Swiss geographer, Brückner, rediscovered this 35-year cycle, which came to be known by his name. Brückner used all the long records of rainfall and temperature then available and was able to extend his study as far back as 1020 A. D. by employing known changes in

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FIG. 1. THE ELEVEN-YEAR SUNSPOT CYCLE IN THE ANNUAL RINGS OF A SCOTCH PINE TREE (AFTER DOUGLASS).

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level of the Caspian and other seas, the records of ice conditions and severe winters, and the dates of poor wine-grape harvests. He recognized 25 cycles between 1020 and 1890; though their average length was 35 years they varied from 20 to 50 years, which suggests that they, too, perhaps were multiples of the sunspot cycle. More recently, Douglass and Huntington have found similar cycles in the annual rings of trees, and the former has made brilliant use of them in dating prehistoric pueblos of the Southwest. He likewise has discovered evidence of dry and wet periods in the rings of fossil trees that flourished millions of years ago. Moreover, seasonal melting of the ice as the continental glaciers withdrew to the north at the close of the Glacial Period produced characteristic annual layers in which Antevs has found cycles, and some 40,000,000 years ago similar deposits were being laid down in the Green River lakes of northeastern Utah and southwestern Wyoming.

Those who have traveled to the Rockies from the East have crossed the short-grass country and have seen the low sod of grasses to which it owes its name. Since the days of trapper and pioneer, these have been known as buffalo grasses, not so much because bison preferred them as because the animals grazed off the taller grasses and left the shorter ones in their wake during spring and fall migrations. When cattle succeeded the bison and were held in herds or under fence, they grazed much more closely than the moving bison, keeping the plant cover in the short-grass condition almost constantly. This effect was naturally greatest in dry or drought years, so that the buffalo grasses logically appeared to be indicators of arid climate. The first suggestion of this relation was made by two young botanists, just on the threshold of ecology, who explored the sandhills of Nebraska in 1892 and 1893, on the eve of a more devastating drought than the West had known before that time.

Almost everywhere, these botanists

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FIG. 2. SHORT-GRASS COVER OF BLUE GRAMA AND OTHER GRASSES IN THE TEXAS PANHANDLE.

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FIG. 3. SHORT-GRASS COVER OF BLUE GRAMA, BUFFALO GRASS AND OTHER GRASSES; SERIOUSLY AFFECTED BY OVERGRAZING AND DROUGHT. "DUST BOWL," 1937.

found a close curly sod of buffalo and grama grasses, and they naturally concluded that this represented the normal forage crop of that particular climate—as it did for the time being. The tall grasses had not only suffered most from drought itself; they also had been grazed so closely that they either seemed to be absent or at least to be unimportant. As a consequence, the opinion arose that short-grass indicated a climate too dry for farming and adapted only to the cattle industry. This view became current among biologists and there was little occasion to doubt its accuracy before the exceptionally wet summers of 1914–15, when tall grasses seemed to spring up by magic. Relicts of the original grassland have since been discovered in all sorts of protected locations, the most interesting and best dated being the cemeteries of frontier towns, while the most wide-spread and extensive are the fenced right-of-ways of railroads.

Exploration during the two decades has proved that taller and shorter grasses live together where the former have not been destroyed by grazing. To make the proof conclusive, small areas of a few acres each were fenced off as early as 20 years ago in various parts of the West, in cooperation with the Forest Service, Biological Survey and state experiment stations. The desired evidence promptly appeared in the form of mixed prairie, so called because a layer of tall-grass developed above the short-grass sod and reduced both grama and buffalo grasses to a secondary rôle. The narratives of early explorers and forty-niners furnish further proof that the original plains vegetation was mixed. However, the most decisive testimony has come from photographs taken by the Hayden geological expeditions in the Great Plains between 1867 and 1870. These pictures depict an undisturbed landscape with a luxuriant cover of tall wheat, spear and blue grasses, beneath which their shorter companions are completely hidden. The omnipresent sagebrush of later days, which has spread widely because of overgrazing and recurrent drought, is nowhere to be seen.

However, in scientific matters as with the daily press, correction is often slow to overtake the original fallacy. On the ground, short-grass seems convincing. Any one who sees it can understand why the view that it is a trustworthy indicator of climate and crops still persists in some quarters. Recent recommendations for the removal of a large part of our western population have been based upon the assumption that short-grass is the natural vegetation of the Great Plains, that this proves the region to be unfitted for crops and that a great reduction in population therefore is imperative. On the contrary, we know beyond question that short-grass is a man-made cover, and we are confident that rain and drought will continue to follow each other as they have done in past cen-

U. S. Geological Survey

FIG. 4. CLIMAX PRAIRIE OF MID- AND SHORT-GRASSES IN EASTERN WYOMING, 1870. PHOTOGRAPH BY W. H. JACKSON, OF THE HAYDEN SURVEY.

turies. If they do, average crop yields for the next 10 years will equal or exceed those of the present decade, with its heavy burden of drought.

II

The first homestead act, of 1862, stimulated thousands of men released from military service to test their fortunes in the fertile prairie soils of eastern Nebraska and Kansas. A few years later they met the first turn of the cycle in the disillusioning drought period of the early seventies, and this misfortune was rendered all the more tragic by the most devastating plague of grasshoppers known in America. These adverse conditions partly checked the wave of migration, but a favorable shift of the cycle for the next 10 years inspired the greatest inrush of settlers known in the peopling of the West. With memories of grasshopper years in mind, pioneer and newcomer alike felt that drought and hard times had passed for good and that the future held nothing but timely rains and bountiful crops. This feeling was capitalized by those with lands to sell or commonwealths to build, and in good faith even men of science gave their support to the myth that the climate had permanently changed for the better as a result of settlement and cultivation. Such beliefs were disturbed by the drought of 1889 and shattered for a generation by that of 1893–95, when the exodus from the parched regions sent a half million settlers across the Missouri River and back to their homes in the East.

The passing of the drought years found a new generation of home-seekers pressing into the Great Plains after two periods of remarkable rainfall, the first lasting from 1905 to 1909 and the second from 1914 to 1916. This later migration was intensified by the war-time demand for wheat, and the severe drought of 1917–19 went almost unheeded amid fabulous prices for grain. A dry year now and then passed with scant notice until the collapse of the world market for wheat produced chronic agricultural depression, which became acute with the crash of 1929 and the onset of general drought a year or two later. To-day, many persons believe that the last seven lean years have been a period of all but

complete failure of both rain and crops. We shall see that this picture is not generally true, even for the most arid districts. Drought is now front-page news, a local dust-storm wears seven-league boots and a true sense of proportion can be secured only by wide perspective extending through decades.

III

We customarily think that the rainfall of a special year shows a fairly uniform pattern of amount and distribution in any selected region. It actually may vary widely, much as it does in a single storm. Almost every one, in these times of fast motor-cars, has had the experience of driving out of one storm and into another. One also may drive from areas where rains have been plentiful to near-by places, where they have been scanty. Close uniformity in terms of well-known regional tendencies is reached only during the driest or wettest years, and even these may show striking local variations. Nevertheless, precipitation is not normally a hit-or-miss affair, for the very nature of forest, prairie and desert demonstrates that rainfall patterns are distinct. No two neighboring localities in the same region can maintain a material difference over a number of years without differing in their characteristic or climax vegetation.

In seeking to explain the alternation of dry and rainy phases within cycles and the chain of consequences that lead to shifting populations, we may logically turn to fluctuations of the sun as the earth's source of energy. Such at-

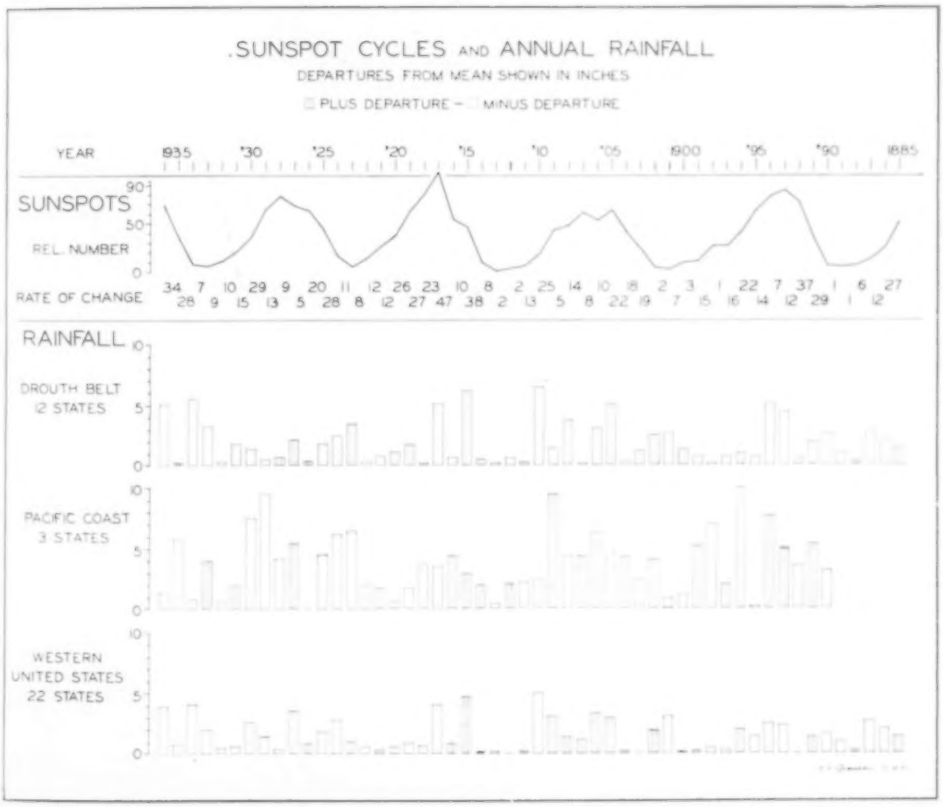

FIG. 5. SUNSPOT CYCLES AND ANNUAL RAINFALL IN THE WESTERN UNITED STATES IN RELATION TO SUNSPOT MAXIMA AND MINIMA AND RATE OF CHANGE IN NUMBERS FROM YEAR TO YEAR.

tempts have been made with increasing frequency during the past 70 years. Most of these inquiries have found some agreement between dry or wet periods and the variations in solar radiation which are indicated by the number of sun-spots; in some studies, at least, the correspondence is striking. In the hope of discovering a connection between drought and sunspot extremes, the rainfall records of all stations in the Middle and Far West were compiled in 1921. The first result of this study was the discovery that the three greatest droughts coincided with the greatest sun-spot maxima (of 1870–72, 1893–95 and 1917–19), when the number of sunspots for each of the three maximal years averaged 85 or more. The alternate maxima of 1883 and 1905 were marked by a relatively low number of 63 spots, and rains were generally good to excellent in and about these years. Tentative forecasts of a maximum of about 100 spots in 1917, attended by serious drought, and of approximately 75 spots in 1928, with normal rainfall, were verified.

Through the cooperation of the Works Progress Administration and the Forest Service, rainfall records are now being compiled in terms of excess and deficit (contrasted with the mean amount) for the whole North American continent. The first fruit of this project is a table of state averages and their annual departures from the mean, beginning with 1876. This table confirms the occurrence of droughts at high sunspot maxima and it also reveals a marked tendency to drought years at times when spots are fewest. Furthermore, it not only corroborates the trend toward normal precipitation at the low maxima of 1883, 1905 and 1928, but also discloses that normal rainfall or better occurs between sun-spot extremes. Fig. 5, based upon this table, does not include the drought of 1870, but it shows that two great droughts fell at the high maxima of 1893 and 1917, while similar deficiencies occurred at the five minima between 1890 and 1933. However, this leaves unexplained the dry years of 1886–87, 1910, 1925 and 1930–31. Their cause is suggested by the fact that each coincides with an abrupt change of 25 to 30 sunspots in the direction of either maximum or minimum.

The periods of good rains in the last half century have been 1875–78, 1881–85, 1902–09, 1914–15, 1920–23 and 1926–28, with frequent single years intervening. Beginning with 1929, the departure from normal in the West generally and in the drought-belt in particular has been uniformly minus, although the deficit was slight in 1929, 1932 and 1935. The dry period of 1929–36 is the most nearly continuous that has been recorded for the United States, but the interval of 1893–1901 was virtually as severe. Bad as it has been, the severity of the recent drought has been much overestimated, largely because of dramatic dust-storms. This reassuring opinion will be supported by a consideration of the potential crop-yields for the past decade.

IV

In a state of nature, probably no living thing escapes the ravages of drought in some form or degree. The effects are felt first by plants and especially by annuals, whose fate depends upon a single season. The great crops of the western world—corn, wheat and other small grains, cotton and sorghums—are annuals, most of which are subject to the whims of a hot summer, when a few days may do irreparable damage. Nature's crops, with the exception of weeds, are largely perennial; this is specially true of the plants that make up the great vegetations or climaxes. It is practically impossible for a drought of several years to do more than stunt them, unless man has complicated the situation. Most insects, as well as many other animals, live as adults during a single season, and resemble annual plants in being highly

responsive to drought. Those of longer life-span, such as birds and mammals, respond more slowly and their numbers fluctuate to correspond, rising or falling during cycles of several years. In the case of grasshoppers or locusts and certain rodents, periodic increase is often so great that it produces veritable plagues, like those which marked the grasshopper years of the seventies. Grasshopper plagues in the West seem to be direct results of migration caused by drought; this relationship apparently has existed in Europe and the Orient since Biblical days. Between the time of Charlemagne and 1862, the migratory locust invaded Europe 132 times, and 22 of those invasions were devastating plagues of the first order.

In the Far North, the periodic shifts in the populations of snow-shoe rabbits or hares are of tragic importance to Indian tribes and to such predators as the lynx, fox and marten, whose basic food is rabbit meat. These variations are the best documented of all animal cycles, since an exact record of the fur trade has been kept by the Hudson Bay Company for more than 100 years. Seton has shown graphically the fluctuations in rabbit numbers and the corresponding rise and fall in the number of the snow-shoe's chief enemies. These variations corresponded closely. There also is general agreement between times of maximal numbers and sun-spot minima, probably because there is greater warmth and better plant growth at such periods.

The last act in the full cycle of climate is the movement of human populations. This, in itself, is a cycle of advance and retreat. There have been four chief occasions for such tide-like movements in the West, in which the advance was timed by superior rainfall and good crops, while backward movement matched drought and crop failure. The first two crises fell in the early seventies and nineties, at times of high sun-spot maxima; the third came at the maximum of 1917 during war-time, with its high markets and greatly reduced man-power, and it consequently received little notice. The fourth and last occurred in the midst of depression, when the machinery of relief already was in action, so that the usual mass movement eastward did not materialize. That the question of enforced depopulation is a critical one is shown by the attitude of the Great Plains Committee. In August, 1936, it expressed the opinion that the region could sustain its existing population; a few months later, it wondered whether reduction in numbers might be imperative. Its final conclusion, which appeared early in 1937, will receive consideration later.

Meanwhile, a nation-wide study of economic conditions, entitled "Migration and Economic Opportunity," has been published, the view set forth in this report being: "In the case of the Great Plains, the minimum exodus 'consistent with safe use of the land' would be a quarter of a million people and the ideal economy would require the removal of nearly three times as many. . . . It is our judgment that the long-run direction of movement must be toward the urban areas and hence there cannot fail to be large movements from agriculture into other occupations." The report goes on to consider what these occupations are and the possibilities of jobs in them. After canvassing the national situation, it rather obviously indicates that there is only one other occupation for the 750,000 people to be moved out of the Great Plains, and that is work-relief.

V

Dust-storms, soil-drift and floods during the past five years have made such a convincing case against man's handling of the soil that the verdict is unanimous and the task is now to carry it promptly and fully into effect. As Dr. Bennett has shown, this is being done with increasing success throughout the Great

Plains by the Soil Conservation Service, and the task of the ecologist as a student of environment is chiefly to analyze the rôle of vegetation in the processes of protection and recovery, in order to obtain a properly balanced control for the future.

There is nothing mysterious about the way in which plants act to hold particles of soil in place, but the combinations of different plant covers, soils, climatic conditions and human disturbances are innumerable. As a result, a matter which is simple in its essentials may become complex in practice. Moreover, vegetation not only protects the soil upon which it grows, but it also exerts a beneficial action for considerable distances beyond. This is easily seen in the case of windbreaks and shelterbelts; and it applies equally though less conspicuously to crops grown in strips, and even to individual clumps of grasses. In all cases, plants slacken the movement of wind or water and reduce or even destroy their power to move loose particles of soil.

This ability to protect soil varies much with the kind of plant and the form of its stem and roots. Tall stems and dense tops make trees the first choice for windbreaks; shrubs and bushes rank next, while grasses and herbs come last. However, when we turn to the control of soil beneath them, grasses move up to parity with trees. The native mantle of grasses, tall or short, forms an all but perfect control of erosion by wind or water and continues to hold the soil against the force of the wind until nine tenths or more of the surface is exposed by overgrazing.

Dead grasses may protect the soil almost as well as living ones, and they perform great service during dry periods before and after the growing season. Stubble gives comparable protection to grain-fields after harvest and permits methods of control in which seed is drilled into the ground without plowing. Stubble also may be saved as a litter which prevents blowing—but not in fields which are summer-fallowed. Since drilling reduces crop-yields greatly, strip-cropping probably is the best compromise between high yields and destructive drifting of soil.

Grasses and grains (which belong to the grass family) have one further advantage. Their greatly branched roots hold the upper layer of soil so firmly that particles often can be removed only with a power-stream. Since comparable agents are rare in nature, these roots give unusually strong protection against soil removal by either flowing water or wind.

Grasses of the Great Plains take two familiar forms, known as *sod* and *bunch*. Bunch grasses are the more numerous, for their habits fit the prevailing dry climate. They usually are much taller than the sod grasses and have larger, denser root systems, but they cover the ground less uniformly than do the sod-formers. This latter group includes such outstanding types as wheat grass, buffalo grass and one or two of the grama grasses —if they grow under favorable conditions. Their stems are spaced closely and uniformly; all but wheat grass are short-grasses whose leaves form a more or less dense mat. They spread readily by means of rootstocks in the soil and runners upon the surface. Thanks to this ability, they surpass other plains grasses in ability to resist overgrazing and other disturbances.

Grasses also are divided into tall, medium (or mid-) and short groups, according to their comparative heights. Stature corresponds closely to growing conditions and especially to available water. The three groups therefore reflect both the amount of moisture in the soil and the rain that falls upon it. Tall-grasses, such as bluestem and sandgrass, require much water and hence occupy valleys or sandhills; the mid-grasses generally prefer sandy loams with less available water; and such short-grasses as

grama, buffalo and wheat grass select the fine soils of the so-called hard-lands. When uncovered, the degree to which these soils will blow is determined chiefly by their texture and the amount of organic matter and water in them. Sand-hills shift about constantly when they are exposed; the others drift less and less as their sand content decreases. It is an interesting correlation that sand, which blows most readily, is covered by the tallest grasses, the intermediate soils chiefly by mid-grasses and the fine, compact silts by buffalo grass. However, the protective values of these three types are much more alike than their stature seems to indicate. Under natural conditions any one of them affords an almost perfect control against the strongest winds.

To appreciate how effectively grasses and weeds protect the soil surface, we need only to notice that they form miniature windbreaks. In this rôle, they reduce the wind velocity for a distance to the leeward that may be as much as 20 times their height. This is several times the distance between bunches of tall-grass and the same relationship holds among the short-grasses, which stand much more closely. Even a very open cover of native grasses will prevent wind erosion: a fact that is readily confirmed when we measure the effects of different grasses upon high wind velocities. Wheat grass completely stills a wind of approximately 18 miles an hour at three inches above the ground-level, while short-grasses decreased it 20 to 25 times.

When vegetation catches and holds soil particles, it keeps the wind from picking them up to form soil-drift or dust-storms. Soil-drift means deposition, which builds dunes on farmlands as well as along sea-coasts and river-valleys; if uncontrolled, it buries windbreaks and fences and overwhelms farm buildings. Obviously, the best method of control is to prevent wind erosion, but until this is achieved generally, deposition must be brought about where it will do the least harm. Windbreaks therefore must be planted far enough to the windward of homes so that

FIG. 6. ABANDONED FIELD IN THE SANDHILLS OF NEBRASKA. IT IS CONTROLLED BY THE NATIVE TUMBLEWEED.

silt is caught and dropped before it reaches farmyards, or an outer low windbreak may be used to catch soil before it piles about the windbreak proper. Russian thistle and other tumble-weeds are especially undesirable because they come to rest along fences and windbreaks and thus produce deep drifts. Such tumble-weeds can thrive, however, only in soil that is cultivated or otherwise disturbed. A pasture strip to the windward of buildings will almost always eliminate danger from them.

Some writers believe that dust storms have occurred commonly throughout the later geological past and that deposits hundreds and even thousands of feet thick were produced by wind action. Without presenting the ecological evidence in detail, we may say that even a thin cover of vegetation controls the wind so effectively that soil-drift and deposition during the past must have been limited to bare areas such as ocean-strands and river-banks. During the historical period, dust storms have come only from soils exposed by man in the course of settlement.

Of all the forces that act upon plant cover to destroy its protective power, those released by man are by far the most potent. The only natural one of great significance and wide extent is drought, though floods and animals may exert much local effect. Even drought is chiefly contributory and the train of events which lead to soil drift and dust storms is regularly set in motion by disturbances due to man. All these—cultivation, fire, grazing, road-building, etc.—lay the land surface bare and provide opportunity for erosion.

The control of wind or water erosion must be accomplished for the most part by means of vegetation; all other aids are merely contributory or are to be employed when the protective effect of plants is absent or while plants are being restored. Wind is more readily controlled than is water, since even an open

FIG. 7. FENCE BURIED BY DRIFTING SOIL WHICH IS HELD BY A COVER OF ANNUALS, RUSSIAN THISTLE AND PIGWEED.

cover does this effectively, not only beneath it but for considerable distance to the leeward. For the nearly complete control of runoff and erosion, a dense cover is necessary. Where cultivation of fields keeps such cover from growing, terraces, dikes and furrows must be used as reinforcements to plants. On the Great Plains, similar aids should be utilized where overgrazing has become a menace during drought and renewed rains will bring volumes of water that the impoverished pastures can not retain until it is absorbed.

VI

So thorough is the control exercised by native grassland that the return of croplands to grass in the Great Plains has come to be generally regarded as the proper, if not the sole, solution of the problems brought in the train of drought and abandonment of crops. This belief, however, has failed to take into account several critical considerations, namely, that drought itself, though recurrent, is always transient, that methods of proper cropping and erosion control have been developed and are being applied with increasing success, and that restoration of

grass-cover involves much more than the mere broadcasting of seed over a landscape.

For two generations, attempts have been made to rejuvenate over-grazed or wornout ranges by the simple device of sowing seed and leaving the rest to nature. Such efforts have been uniform failures, except under moisture conditions that rarely occur. As a consequence, we have been forced to look more closely into nature's ways in order to discover how she succeeds in improving pastures and re-covering abandoned fields when given the opportunity. With these facts in hand, we are able to speed up natural processes, to use other or better plants than those now available and to broaden the field of action. More than this, we can press into service some of the practices of cultivation and can secure combined forage and protection values resembling those found in fields of perennial crops. In such cases, the problem is narrowed to finding and maintaining the best grass crop and, of course, to securing the man-power or money needed to do this work.

FIG. 8. A ONE-TIME CLIMAX MIXED PRAIRIE IN EASTERN COLORADO. OVERGRAZING AND DROUGHT REDUCED IT TO SHORT-GRASS; CONTINUED OVERGRAZING AND DROUGHT DESTROYED MOST OF THE SHORT-GRASS, WHICH NOW IS REPLACED BY PRICKLY PEAR.

When does grazing become over-grazing? The best answer is that this happens when weeds begin to increase in numbers at the expense of grasses. Since two compete keenly for a limited water-supply, anything more than moderate grazing throws the balance in favor of the weeds. The grass then decreases in amount, but since it is still called upon to support the same number of cattle, it suffers further handicap in its struggle with the weeds. Each step in the destruction of the forage cover is marked by the appearance of other weeds, until these competitors become masters of the situation. The carrying, or grazing, capacity of the land may be reduced to a half or third and its protection against water erosion and flooding may be cut even more. So characteristic are weeds as indicators of the successive stages of deterioration that the forage production and protection value of a particular range may be estimated from the kinds and abundance of the weeds in it. When drought comes, the remaining grasses have less water for growth, competition is intensified and the demands of cattle are relatively increased. The result is that the grass cover loses ground at an accelerated rate until (to the unpracticed eye) its ruin seems complete. But fortunately, while grass may be eaten down to the roots, it is rarely if ever eaten out, but persists and is ready to renew growth under more favorable conditions.

The best cure for the ills of overgrazing is to be found in the natural recuperative powers of grasses and the chief task is to afford them a fair opportunity. Natural recovery is so much more automatic and economical than restoration by sowing or planting that it should always be given an adequate test before artificial methods are used. The essential requirement is a resting spell in which the grasses may make and store food for growth; this demands a reduced number of grazing ani-

mals per acre. Complete removal of cattle for a year or two is often desirable, but too frequently it is impossible, especially during drought. Instead, herds must rotate from pasture to pasture or grazing must stop during a special period. Since grasses are most susceptible to damage when they are becoming green in the spring, spring grazing generally should be deferred as much as possible. Delayed grazing demands an adequate supply of fodder, a fact that makes the general development of forage crops an indispensable feature of any successful farm system for the Great Plains.

The question of how far artificial regrassing is desirable must remain open until the method has been tried in the various climates and covers and the cost of assured results is determined. However, where erosion is active and the flood risk to large cities is great—as it is on the divide between the Platte and Arkansas rivers—the cost of restoring an effective cover is much less important than the speed with which it can be done. In all such areas sowing and planting should be used to hasten recovery as much as possible. Unfortunately, two of the best species for this purpose, buffalo and wheat grass, are not well adapted to this region, while a moderate reduction in stock for a year or two and regulated grazing thereafter probably would remove flood danger to cities along the mountain front. These measures must be reinforced by terraces, check dams and reservoirs to provide assurance against the occasional torrential rains which are popularly known as cloudbursts.

VII

Each receding wave of population on the plains has left in its wake thousands of abandoned fields whose management has reverted to nature. She has taken these areas in hand and in her own deliberate fashion has called in a succession of plant communities to re-establish the grass cover, beginning with weeds the first year. In some instances, this restoration of grass was a relatively simple matter; in others it was exceedingly difficult. Deep-seated disturbance, lack of a proper supply of seeds and recurring dry years hampered progress. Worst of all, such fields frequently were too quickly returned to grazing—often in the first weed stage or even by utilization of the abandoned crop. In consequence, large areas of the Great Plains are checkerboards of abandoned fields in all stages and degrees of recovery. They can be fashioned into a nicely graduated scale for the study of regeneration and utilization.

For hundreds of these fields in various districts, Savage, Judd and other workers have been able to determine the year of first or renewed cultivation, the number of years under cropping, and the date of abandonment, which determines the length of the period during which succession has acted to bring about natural recovery. The most significant discovery in this connection is that succession operates most rapidly in fields of the "suit-case-farmer," usually a city-dweller who leaves his desk or bench to sow a crop

FIG. 9. A SUIT-CASE FARMER'S ABANDONED FIELD WITHIN FIVE YEARS, IT HAS BEEN RECLOTHED BY SPEAR-GRASS AND WHEAT-GRASS.

and return later to harvest it. He embodies all the undesirable practices in cropping, plowing his field sketchily at the outset and drilling the wheat in each year without further cultivation. His methods are poor, but he does not destroy the underground perennial parts of the native grasses, which may survive as many as 16 successive crops and still be ready to reclothe the soil effectively in three to five years. Fields in sandy soils or sandhills likewise permit rapid succession and again become covered with characteristic stands of tall bunch grasses in about eight to ten years. If land values warranted it, artificial aid would doubtless hasten the process.

The situation is quite different in the finer soils of the so-called "hard lands" where cultivation has been more thorough, usually to the extent of some ploughing for each crop. Rootstocks may survive for two or three years, but in the great majority of the fields that have been abandoned four years or longer, succession depends upon seeds and hence proceeds very slowly. It is possible that some seeds remain alive in the soil for several years, but as a rule they must be blown in from adjacent areas where grazing is moderate or absent and grasses are able to produce seed. Roadsides, railways and other protected areas furnish the chief supply, especially where they lie in the direction of the prevailing wind. But under such conditions the ground is largely bare at eight to ten years and still about half exposed at 18 to 20 years, while the normal cover is usually restored only after 30 to 40 years. Obviously this is far too slow, even if grazing can be excluded, and recently abandoned fields of this type can be promptly returned to grass only by artificial methods, such as sodding with buffalo grass. Fortunately, the great majority of existing fields are now well along in the process of natural succession. Some will require no aid and others a relatively small amount, while those withdrawn from cultivation during the past five years will need complete artificial treatment, where it is deemed best not to return them to crop production.

VIII

The ecologist looks upon grassland in general and the prairies and plains in particular as almost inexhaustible reservoirs of soil fertility—of the raw mineral materials which are essential not merely to plant growth but especially to high yields. It was not by chance that grasslands of the Mississippi and Missouri valleys became the scene of the greatest corn and wheat production in the world. There were many reasons for this, but the most significant were depth of soil, abundance of available humus and minerals, presence of lime, readiness of nitrification, and number and abundance of nitrogen-fixing plants. Virtually the only limiting factor was water, whose amount was restricted by rainfall which decreased progressively to the westward, and by recurrent periods of drought. Under these conditions the advantages of wheat, especially winter wheat, soon were recognized and this grain came to be the major and too often the sole crop of the region. In spite of drought, sagging markets and justification for an expanding grazing economy, wheat continues to hold its preeminent position.

The point to be emphasized is that under proper tillage wheat has produced a fair and often a large return for a quarter of a century throughout most of the Great Plains. When it has failed more or less completely in large areas, failure has also swept across much of the subhumid Missouri Valley. In spite of its greater requirements and longer period of exposure to the vicissitudes of summer, corn also has been a profitable crop, especially when the value of forage or stover is considered. This is even truer for the grain sorghums such as milo and kafir.

The most significant fact for the solution of the population problem in the

FIG. 10. AVERAGE WHEAT YIELDS IN BUSHELS PER ACRE FOR THE DECADE 1926 TO 1935, AT EXPERIMENT STATIONS OF THE DIVISION OF DRY-LAND AGRICULTURE, U. S. DEPARTMENT OF AGRICULTURE.

Great Plains is to be found in the yields of grain, and especially of wheat, at the experiment stations of the Division of Dry Land Agriculture. Along the eastern line of stations from North Dakota to Oklahoma, average wheat yields for the decade ending with 1935 ranged from 17 to 31 bushels per acre. In the western series of stations, with a rainfall several inches less but with the compensation of higher elevation, yields were practically the same: 17 to 30 bushels per acre.

With respect to balanced cropping and the feeding of stock, the average yield of corn was 20 to 22 bushels per acre, while milo ranged from 23 to 34 and kafir from 21 to 25. The fodder as a rule approximated two tons per acre.

Yields on farms in these same regions were much lower. But no one conversant with the situation expects to save agriculture and the farm population in the Great Plains by a continuance of the practices that have brought about existing conditions on average farms. The Soil Conservation Service's achievement in winning the great majority of farmers to cooperation in its demonstration projects, and in securing results far out of proportion to the brief period of its existence, shows that western agriculture can be, and is being, improved. Moreover, a direct and complete answer to the question is furnished by Charles Peacock's farms in eastern Colorado, where basin furrows are employed to retain all moisture that falls in a region whose yearly precipitation is about 16 inches. This device, coupled with a generally excellent system of tillage, has produced yields of 18 to 22 bushels of wheat per acre each year since 1932, with the exception of 1935. Failure in that year was due to grasshoppers, which took the winter wheat as fast as it appeared above ground in the fall of 1934. Since these farms enjoy no peculiar natural advantage, their crop-yields fully support the results achieved at the various dry-land stations. When the two sets of yields are combined, they leave little room for doubt as to the Great Plains' capacity for wheat production. In fact, the yields obtained during the decade of the most serious drought in our history compare most favorably with normal averages in the more humid districts several hundred miles eastward.

IX

Almost every one admits that a method of long-range forecasting as accurate as the daily predictions of the Weather Bureau would be one of the greatest conceivable boons to agriculture. The greatest achievement in this field has been the prediction of monsoon rains, by means of which the threat of famine has been reduced in India. In this country, McEwen's October predictions of winter rainfall in southern California have been so successful that his researches have re-

ceived financial assistance from utility companies interested in annual forecasts of hydro-electric power. During the 21 years of forecasting, he has obtained an agreement of 75 to 80 per cent. between predicted and recorded rainfall. For southern California, McEwen made 15, and for the Santa Barbara region 17, successful forecasts during these 21 years.

The physical system in the interior of the continent is more complex than that of the Pacific Slope and demands different methods. In the tentative effort to find a basis for prediction of rainfall in the Great Plains, solar radiation in terms of the sun-spot cycle has been the chief reliance. This has been supplemented by correlation between the rainfall of this region and that of California, where Santa Barbara is under test as a key station because of its intermediate position. This correlation has amounted to 70 per cent. since 1896 and 80 per cent. for the past 15 years. It possesses a unique advantage for prediction year by year, since California rainfall precedes that of the growing season in the Middle West by 6 or 7 months.

The first attempt to anticipate major fluctuations in rainfall on the basis of the sun-spot cycle was made in 1913 and was confirmed by a moist season. The second tentative forecast, made in 1916, anticipated the drought of 1917 from the number of sun-spots at the approaching maximum, while the third suggested fewer that 80 sun-spots for the maximum of 1928, with generally good rainfall. The drought year of 1930, which ushered in the recent dry period, was wholly unexpected, since the apparent significance of a rapid change in numbers of sun-spots had not been perceived at that time. This new index suggests a plausible explanation of drought in 1930–31, with a rate of change of 29, and in 1936 with one of 32 spots, while the sun-spot mini-

Courtesy of the Soil Conservation Service

FIG. 11. ROASTING EARS FROM THE CROP OF FIELD CORN GROWN ON THE LEVELLED DUNES IN 1937; PHOTO BY WHITFIELD.

Aerial Explorations, Inc., New York City

FIG. 12. DUST CLOUDS FROM UNTREATED LAND IN OKLAHOMA. THEY SHOW THE NEED FOR COMPLETE COOPERATION TO CONTROL SOIL DRIFT, DUNE FORMATIONS AND DUST STORMS.

mum of 1933, which carried over into 1934, is thought to explain these dry years. The present course of the sun-spot cycle indicates a high maximum in 1938, and the forecaster is torn between the desire to see the sun-spot indexes again confirmed and the hope that good rains will temporarily contradict them.

X

Nearly 30 years ago, in connection with a classification and use survey of Minnesota, it was suggested that the farmer might well emulate the ecologist and carry a soil augur for measuring the amount of moisture in his fields. Hallstead has put this method to eminently practical account at the Hays Experiment Station; he has also shown that the farmer needs only a spade to learn the depth to which the soil is wet enough for plant growth. This depth at seeing time is closely related to the yield of wheat, a moisture layer of three feet in fairly heavy soil virtually insuring a good crop. With a shallow, wet layer, failure is frequent, and when dry weather occurs during autumn or winter, abandonment often is desirable.

The most significant outcome of the practice of testing soil moisture is that it permits an early and impersonal decision as to the advisability of abandoning the growing crop and conserving water for the next one by means of fallow, which serves to keep down weeds. In short, it gives the farmer two chances for a good wheat yield, since fallow usually produces twice as much as continuous cropping. An important item is that moisture determinations render a fairly decisive judgment at a time when the farmer is still inclined to gamble on rain. With the water-content low and rainfall deficient to April first, abandonment of the crop and the use of summer fallow is strongly indicated. To harvest the wheat crop in good years and abandon it in poor ones gives the flexibility needed in a region where dry years are not rare and drought periods are recurrent. It is a type of crop insurance that requires neither subsidy nor enormous granaries, and is peculiarly adapted to maintain the independence of the farmer while it stimulates his thinking processes.

A necessary adjunct to the combined method of anticipation and prediction is the adjustment of crops to seasonal differences in rainfall and soil moisture. In general, corn requires more water than winter wheat, wheat more than grain sorghum, which in turn uses still more than the various forage plants. The special needs and values of the different crops for the diverse regions of the Great Plains have been so thoroughly demonstrated by the various state and federal experiment stations that the information necessary is available to every farmer. The prerequisite to its general use is advance information about the farmer's capital in terms of moisture. We have found that the most important forecast can be made by the spade, but it is not improbable that this can be reinforced and anticipated year after year by means of long-range indexes.

When we turn to the related questions of population and relief in the Great Plains, two or three outstanding facts appear. The first is that in spite of a critical drought period, unequalled in duration, the population of the 10 plains states has remained virtually stationary. Obviously, this stability has been greatly helped by relief and subsidy, but these factors were not peculiar to the Great Plains. Since the population maintained itself during this most tragic of times, there is little prospect, and no necessity, of transplanting it during better years. In a sense, the farmers and ranchers of the Great Plains are still pioneers, with characteristic hardihood and attachment to wide horizons and the accompanying defects of mobility and slight feeling for cooperation. But they live on an economic and cultural level far above that

of the hill-billy and share-cropper, and by comparison constitute a simple problem. All the facts agree in demanding that their problem be solved in their own familiar environment.

The ecologist long familiar with the Great Plains entertains no doubt that this can and will be done. From the very outset, he hoped that the winds which had fashioned the drifting fields into dunes 30 feet high and a half mile long could be tamed and forced to blow them down again. This has now been done in the area once thought to be ruined beyond redemption, and crops of corn and sorghum were grown upon the flattened ridges during the summer of 1937 (Whitfield, 1938).

The most serious defect in the past has not been that of climate, natural vegetation or potential crop production. It has been the common failure to realize that the price of continued use is conservation and that conservation can be secured only by means of the most thorough cooperation. First of all this must embrace all the official agencies, federal, state and county, in any way concerned with the problem; this unification has already been accomplished to a considerable degree. It has shown farmers the necessity of cooperation among themselves, and it is upon this new development that the conservation of tomorrow should build an enduring system of use without abuse.

These ecological considerations were brought to the attention of the Great Plains Committee shortly after its pessimistic statement of October, 1936, with the consequence that its final recommendations to the President were summarized in these words:

"In this task of realizing the true and lasting values of the Great Plains, the whole nation has more than a sentimental stake. The Great Plains can be made a dependable source of a large portion of our essential food supply. Investments in their development can be secured from uncertainty, and under proper conditions new investments can be made securely. The Plains can be transformed from a risky adventure and a recurrent liability into a stable basis of economic and social profit to their inhabitants and the whole country."

THE CLASSIFICATION OF INVENTIVE IDEAS

By WM. I. WYMAN

U. S. PATENT OFFICE

BEFORE the boom broke, almost 100,000 applications for patent were filed annually in the U. S. Patent Office. The direction in interest of the coming generation is emphatically towards things mechanical. Large numbers of our population are invention-minded—if not in practical effort, at least in dreams visioning some contrivance of revolutionary effect which would incidentally leave them famous and wealthy.

Assume that our inventor has conceived something that he thinks will urge the public to beat a path to his door. Before filing an application for patent he determines to make a personal survey in the Patent Office files of the things already patented. He finds copies of over 2,000,000 American patents arranged in so-called classes and subclasses. Searching through them in the limited group in which he is interested they appear to him, uninitiated, like the sands of the sea in their overwhelmingly bewildering array. Our novice may have contrived some sort of automatic control to be used in a harvester machine, but of such general application that he is directed to search in the sub-class defined partially as "mechanisms for releasing or tripping portions of machines to cause other portions to automatically operate." He is also officially directed to search cognate subclasses in "Harvesters," "Metal Tools and Implements," "Printing," "Railways," "Motors, Expansible Chamber Type," "Brakes," "Electricity, Circuit Makers and Breakers" among a few others, where similar mechanisms may operate in conjunction with various mechanical features identified with such devices. Before he is through with his quest he becomes conscious for the first time of a different order, of a mechanical existence in diversity of association and in variety of direction beyond his conception. But why should there be any intricacy about it? Surely, steam-engines, hair-pins, radios and carburetors, to name a few items at random, are distinctly different things and no trouble should occur in placing them in different categories. And yet the government has spent hundreds of thousands of dollars to found a scheme that would group like things in classes available for the purpose for which the Patent Office was organized.

To bring like things together to form distinct groups and to separate groups according to their distinguishing properties are measures that consciously or unconsciously have been adopted by humanity from time immemorial. This cerebral process is a method of classification and is not only the basis of any scientific system but is an active principle in all systematic procedure. All ordered thought is based upon it. All ordered performances require it. Dictionaries, directories, correspondence files and trade catalogues are instances of modern requirements in domestic and business life.

The ancients had a good grasp of "logical" classification. They recognized that a class of things may be called a genus if made up of two or more species, that the latter must not overlap and that the division must be founded upon one basis. As an example, it is absurd, as all authorities on logic realize, to divide books into cloth and leather binding, French, German and history. Here are three distinct standards of identification, which overlap and through

lack of a single basis of distinction defeat the very purpose of true classification. If a purchaser expressed a choice between a French book and one bound in leather, the irrelevancy would at once be apparent.

The "state of the art" is the record of nearly all human achievement in tangible production. The term looms large in the process of granting patents and in litigating them in the federal courts. In published form it is expressed in the two million patents granted in this country and the three million foreign patents, as well as in libraries of thousands upon thousands of technical books and periodicals. The untold millions of facts expressed in these publications comprise the record of prior knowledge and act as a determinant of the novelty in an alleged invention. Upon this evidence, the Patent Office proceeds and the courts decide. The patents in classified arrangement form the vital part and the bulk of the "state of the art" and are not only the foundation stones of the patent system, but offer by far the most comprehensive display of the present state of our industrial complex and the most accurate historical record of its progress.

Patent literature discloses wasted endeavor as well as assured accomplishment. Much ingenuity, hard intellectual labor and protracted effort, not to mention untold expenditure of money, have gone into futilities, into misdirections, before the proper clue to a successful approach was discovered. Almost every art shows such periods of vain endeavor, of error in principle, that preceded the basic invention that gave proper direction to subsequent progress. A case in point is the linotype. Hand composition of foundry type, with its limitations as to output, the waste of time and effort in distribution and other irritating ineffectualities, was known for over a century to be an anomaly with relation to the advanced status of the rest of the art. All sorts of efforts to speed up the process were attempted, resulting in mechanical expedients that were nothing short of extraordinary. Such was the Paige composing machine, probably the most intricate mechanism completed by one man in all history. Mark Twain sunk several hundred thousand dollars in the invention, which when patented was disclosed in a document containing 163 sheets of drawing, 471 figures and 55 pages of printed text. It endeavored to simulate the complex movements of hand composition. But the solution of the problem was not in that direction or through any mechanical means for the selection of individual type. Even when the thought is grasped that is the kernel of successful development, failure may result if its essential embodiment is not discerned. Such was the origin of the linotype. The first thought was the idea of impressing a mold with type characteristics. It failed in practice. Mergenthaler started from that point and derived the essential element that required incorporation in the successful machine. Here, failure pointed to success, and the well-known individual brass matrices, selected by keyboard action to form a line of mold characters, was the result.

Other instances can be cited. The first effort to propel ships by steam simulated the action of hand-operated oars; the successful airplane was preceded by contrivances imitating the flapping of the wings of birds; and the first successful automatic railroad car coupler came after hundreds of contrivances were patented that followed the line of intellectual least-resistance. The course of inventive progress is shown in these two million patents. They form an impressive panorama of the evolution of our material civilization. If they picture strivings that resulted vainly, they also depict attempts which led to fruitful performance. If they show ideas of indecisive nature, many of them indicated the germ that formulated the principle

of the successful invention. They also tell the story of the rise and fall of endeavors and industries as the automobile era outmoded the horse and buggy age. In any event, the grant of patents acts as an incentive to inventive productivity, which typifies our present civilization as truly as the cathedral builders of the thirteenth and fourteenth centuries reflected that era, or the fine arts the succeeding centuries of the renaissance.

This leads us to consider the so-called "lost arts" of the ancients. There is little authority for much of such belief. But right before our eyes we see the process of arts becoming "lost" actually going on. Obsolescence indubitably follows invention, making for a new economic set-up. It would be suicidal in a competitive society to retain outmoded and relatively uneconomic processes and mechanism. Particularly is this true in machinery replacements for manual operations. Not that the latter is "lost" to knowledge, but that they are no longer needed in practice. These superseded arts, especially in the way of doing things, are typified by the "horse and buggy age" which has been so much emphasized through replacement by the automobile era. Almost everything typical of that age has become a discarded art. The very road over which the buggy rolled has given way to a pavement of radically different manufacture and characteristics, absolutely required by the demands of automobile traffic.

The reciprocating steam-engine, the initiator of our mechanical civilization, is itself being junked to make way for the turbine and the Diesel engine as a source of convertible power, and the electric motor for direct application to stationary machinery. In a more humble capacity but of more general experience, we can point to shaving with the old-fashioned razor, outside of the barber shop, as a "lost" art. So through mechanical means are becoming many arts in the household, whose mistresses "find" time to acquire new arts for the exploitation of their acquired leisure. The instances may be multiplied *ad lib*, most of which are known to the general reader, and further examples need not be cited.

The intimacy of our material progress and patent activity is not generally appreciated. Hardly any change due to invention but what is recorded in this "state of the art"; and hardly any advance in the applied sciences which have so vitally changed our whole economy that is not the subject-matter of patent protection. How rapidly that advance proceeds is illustrated in a late report of the U. S. Steel Corporation, which records that $280,000,000 was written off as recognition of the obsolescence of machinery and equipment the last few years. This is a striking instance of how progress marches on. An extensive program of construction and rehabilitation in view of such obsolescence will be required.

Another instance of this kind is given by B. C. Forbes, the well-known economist, who cites the report of Thomas J. Watson, president of the International Business Machines Corporation:

> To-day more than 95 per cent. of our profits are made from things developed in our own engineering department. Last year we were issued 81 patents carrying 803 claims. Our total patents now aggregate 874, with 10,134 claims. We have spent $9,200,000 on development and patents in 22 years, and last year our expenditure in this respect was the largest in our history.

There is such a large demand from patent attorneys, inventors, manufacturers, research institutions and technical government bureaus for copies of these patents that Uncle Sam keeps about 50,000,000 of them for sale and disposal constantly on file in steel cases covering over 35 miles of shelving, of a design unique to this country, for rapid and accurate disposition and economical and clean storage. They comprise the infor-

mation which forms the basis for new ventures, for the extension of manufacturing plants and for the security of existing industries, as well as the working tools of the Patent Office examining force.

We readily perceive, then, why the division into groups of this record of the "state of the art," mostly copies of patents, is a critical concern for the ascertainment of the facts it contains. Practices in other activities offered no examples that could be followed in the unique conditions presented. The broad principles of classification known to the logicians as far back as Aristotle have been adapted where applicable. The biological sciences, where classification was developed to the most amazing extent, provided no model, although we must marvel at the results of modern nomenclature with its swift capability of ascertainment of specific characteristics leading to definite identity of myriads upon myriads of species into which all organisms are divided.

The original scheme of classification followed the lines of least resistance, the patents being arranged in accordance with their relation to particular trades or industries. Jefferson, who first administered our patent system, laid down the rule that a new use of an old machine does not constitute an act of invention. Nevertheless, a new arrangement of old parts may. That is why any division along accepted trade requirements does not constitute a complete standard for purpose of Patent Office examination. Many devices which the public will generally recognize as constituting distinctly different mechanisms, applied to different pursuits, will be held analogous by the Patent Office and the courts because composed of the same association of parts, operating under the same principle of action and producing similar results, proximate if not ulterior. In response to this theory, machines for agitating liquids, for washing and for churning may be held identical; so may an apparatus for mixing air and gasoline vapor and one for mixing illuminating gases having the same structure and operating under the same physical rules. Fluid motors, pumps and meters offer other examples of identity. The law, as laid down by the federal courts, takes no account of ultimate motive, of purely mental figments, but only of the effective elements that combine to produce the result. That is why classification frequently cuts across some of the established lines of industrial distinction, because it would be impossible otherwise to perceive what is "patentably novel" in a complex cosmos of mechanical elements, materials, performances and devices capable of being assembled through permutation and combination into an unlimited number of associations detectable in many diverse industrial arts.

This discussion may seem an abstraction, but is real and vital enough to the profession. To give a concrete illustration, contemplate the organization of an automobile. We perceive the transmission gear, also useful in lathes and machine tools generally; batteries and dynamos, used in generating current for lighting, heating and power purpose; and the body, the wheels, the windows and the chassis, which may include elements common in railway cars, building structures and ventilation; or its ancestor, the locomotive, in which the boiler, the engine, the valve-gear and other accessories, are found to be essentials in all steam-engineering activities for stationary and marine installations. In all industrial applications there are included elements having analogous associations in various other industrial pursuits, and there is no end of interrelationship and extensions, making it scientifically impossible to restrict the operations and influences of inventions within the confines of pigeon-holes limited to the lines of trade boundaries.

Having become conscious of the scheme

considered to be appropriate for patent classification, it is enlightening to look into a few of its applications. It will be perceived at once that any conception arising out of general knowledge, no matter how wide and deep, of the variations in any class of subject-matter that may be patented is astronomically distant from the mark. Let us consider first the recently reclassified class of machine elements—the "phrases" and "clauses" of machine assemblies. It is officially defined as "Mechanical combinations, constituting portions of machines, and consisting of two or more fixed and movable parts so combined that the motion of one compels a completely controlled or constrained motion of the others according to a law of operation inherent in and depending on the nature of the combination." There are over 600 subclasses, the main ones being "Mechanical movements," "Gearing" and "Control lever and linkage systems."

The gear in art and design has symbolized the machine for years, but the automobile has accentuated its function more than all previous agencies in history. It has introduced refinements and new operations that are bewildering in range and intricacy. Only a tour through the mazes of patents in this distinctly small portion of all the mechanical arts can give one a fair idea of this ultra-modern development. It comprises about one half of the sub-classes under Machine Elements. The group of species under the genus "Interchangeably locked" provides the largest assembly, and as partially defined they comprise "Transmissions in which a plurality of speeds are transmitted from one shaft to another by optionally engaging or meshing selected gears or clutches." Any one who has fooled with the insides of an automobile or who has even scanned its illustrated literature has a fair realization broadly of this arrangement, the well-known "transmission." All the more reason will he wonder at the why and wherefore of all this complexity. And yet each species represents clearly defined association of related mechanisms whose common functions are manifested by a single group definition. So while even the skilled mechanician may not place his stamp of recognition on the title of the highly specific subclass 367, the Patent Office has found it essential for economy and certainty in making an examination to create it, which reads in full: "Gearing, Interchangeably locked, Slidable keys or clutches, Single clutch shaft, Progressive, Single key, Reversible driver one way driven." That he may test his powers of comprehension let him read the official definition: "Transmissions which may or may not permit of a change of speed and wherein a plurality of shafts have constant mesh gears mounted on them, the gears on one shaft being rotatable thereon and being adapted to be clutched to the shaft by means of a single slidable key or clutch, this key or clutch being shifted in opposite directions according to the direction of rotation of the drive shaft."

It is not intended to make even a superficial analysis of this class, much less to make any sort of descriptive attempt of the remaining 300 classes comprising the total patent literature. It will be enough if some picture of a small specimen of the entire scene be apprehended so that an impression may be received of the unique character of patent classification, its intricacy and vast scope, some of its picturesque aspects and its departure from accepted concepts. In the examples of subclasses above given, the series in descending scale from the most comprehensive genus to the most limited species is made complete. There is thus exhibited the refinement that classification sometimes has to undergo and the fidelity to the ancient principles of division that is maintained once the group is segregated. And all this because the patents representing

even an industrial art have developed not necessarily along the lines of trade cleavages but frequently in directions totally at variance with them, making it essential to mark out these tendencies as standards with which contemporaneous efforts may be compared. Of course, if tendencies take new directions, as is constantly the situation, the classification takes cognizance of them by appropriate amendments when the new patents depicting the new aspects become available.

A further consideration vital for classifying is the psychology of the inventor, which urges him to a mental approach to a problem which defies preconceived analysis based merely upon what is customary. What association of mechanisms or functions he may exhibit or what particular directions his fancy may take, is impossible to predetermine. To arrange all such possible mental patterns in advance of their exhibitions so that they can fall into natural groups, or even to do so after they become disclosed, is a problem not present with anything like the same difficulty in any other line, scientific or practical.

An example is the newly reconstructed class of cutlery. There are 63 main points of contact with other devices, such as it would be impossible to conceive of by others than those highly specialized, endeavoring to cover thoroughly a field of almost limitless extent. A glance through the list of arts contacting this one in which it is discovered there are common features discloses such diverse devices as "Compound Tools," "Abrading Machines," "Quarrying and Ice Harvesting," "Gear Cutting," "Butchering," "Roads and Pavements," "Leather Manufacture," "Farriery" and "Label Pasting and Paper Hanging." The interrelation of the arts, their interdependence and the difficulty of attaining any sharp demarcation are thus convincingly exhibited.

This is also well illustrated in the rapid development in recent years of inventions in razors. Less than 15 years ago, only two subclasses were found necessary to divide this art. A little more than a generation back this cutting implement was known to the generality of observers only as a wicked-looking, ultra-sharp, concave-edged blade with a swinging handle in a constant state of unequilibrium. It was dangerous enough to the innocent novice when used for its legitimate function, but carried implications of more serious import when otherwise wielded. To-day, in the search for safety, comfort and automaticity, it takes about 70 groups to properly arrange its various manifestations. Some of the possibilities so recognized, although absolutely unfamiliar to the "boss barber" of the preceding generation, are razors combined with means which permits the sharpening of the blades; in which a magazine holding blades is incorporated in the instrument; or provided with arrangements for collecting waste, such as lather or hair; or for cleaning the razor; or for vibrating the cutting edge; or for giving motion to the blade by frictional contact with the shaving surface.

Some of the classes conform in title and subject-matter to public conception. Dentistry is an example, and a glance through its list of 71 subclasses will recall to the sensitive sufferer many an instrument of torture or many a torturous moment. And yet the searcher for comprehensive information is further directed to a variety of conflicting or complementary devices. It is difficult at first to learn why he should have to scrutinize the class of "Brushing, Scrubbing and General Cleaning," which picturizes boot-blacking appliances, street-cleaning apparatus and vacuum cleaners, but that is where he has to look to find what is old in tooth-brushes. So it is for tooth-picks and dental cuspidors, which are respectively classified under "Toilet" and "Baths, Closets, Sinks and Spittoons."

Allied to dentistry is the official class of surgery. The array of murderous-

looking instruments and mysterious appliances and applications in that class are even more pronounced. Under "Diagnostics" we perceive "Specula, non-pivoted gags"; under "Orthopedics" we find "osteal adjusters"; "Bandaging" provides a generic supply of many features relating to "Fracture apparatus"; "Trusses" are of greater variety in appearance and function than any common garden species of citizen could possibly comprehend; "Medicators" include "Syringes" provided with mechanisms actuated by screws or racks; while the branch of "Instruments" comprises enough appliances to cut, shear, saw, puncture, abrade, rasp, squeeze, compress, distort, fracture, dislocate, relocate, dilate or agitate any anatomical or sensitive feature of the human body to an extent not approached by the unrefined devices shown in the Nuremburg torture chambers displaying the most efficient practices in the administration of medieval justice.

A notable recognition of present-day highly specialized activity is the establishment of the new class of "Chemistry, Fermentation" with 146 subclasses. It has broadly to do with a chemical change caused by an enzyme functioning catalytically. Illustrative of its character is the full title of subclass 46: "Ultimate processes; Carbohydrates, fermentation of; Fermentation to non-carbohydrates; By bacteria only; Butyl alcohol and acetone production; With preformation of ferments therefor; Acclimatization or immunization of ferments." This class, however, does not exhaust all biochemical activities, for others of which we are directed to "Plant Husbandry" for sprouting or germinating seeds for planting; to "Fertilizers" for fertilizers that contain bacteria; to "Foods and Beverages," for alcoholic beverages, malt extracts or other "alimentary" compositions that contain bacteria; and to several other classes where bacteria or ferments are utilized.

Every one is cognizant of the rapid development of the airplane. The Patent Office officially recognizes the same in its recent recasting of the class of aeronautics. In its superseded form there were 31 subclasses. The present arrangement provides for 155 subclasses in that class. A glance through them visualizes at once the changes that have taken place since the Wright Brothers were first active and the extremely technical nature of that advancement. Under "aircraft sustenation" are perceived fuselages and struts arranged to act as "sustaining airfoils" and various designs in the structural parts to alter the amount of lift or to vary their effect responsive to changing conditions. Propulsion, steering and power plants having special relation to aircraft navigation are recognized, especially with regard to the tilting of the aircraft and for high altitude purposes. Then, many patents are grouped under "Aircraft control" in which automatic devices are used and which provide for ballast regulation and buoyancy variation. Landing gears, brakes, special structural features and safety devices galore are also enumerated. And contacts with many other arts are indicated, proving the lack of self-sufficiency in all the arts. The frame work, windows, insulation; the power plant; and the rudder and steering devices have many features in common with building construction, vehicles, marine propulsion, internal combustion engines, power plants and ships.

Scattered throughout the patent literature are many frivolous and ridiculous "inventions," but proportionately they form a minute percentage. The great bulk of the patents are granted on serious, meritorious, practical attempts to "advance the state of the art." Even toys may be included in the latter category, some of which exhibit mechanical expedients calling for ingenuity amounting almost to genius.

Reminiscences of the days when

square-riggers dominated the seven seas arise in scanning the classification of "Ships" in such salty-sounding terms as "Cringles and Hanks"; "Clews and Thimbles"; "Bitts, Cleats and Pin Rails"; and "Spikes, Pins and Fids." Acoustics provide in part that sound waves be propagated under conditions of favorable receptivity so that the sound may be distinctly heard, and then under contrary conditions in the subclasses of "Mufflers," which are officially described as "devices for attenuating sound."

Recollections of earlier customs are also induced by an inspection of the last-named section of the variegated class of "Baths, Closets, Sinks and Spittoons." Except for a few of the 28 subclasses directed to this group of spittoons, this is a dying art. There is some activity in dental lines and in so-called pocket or paper receptacles. Some of the subclasses relate to devices laid in the floor and having rather complicated piping for flushing. A peculiar subclass comprises a few patents for association with a bar providing a community service for the expectorating customers. Although the pre-prohibition era has been revived, patents for this relief appear no longer sought for. Most of the patentees in this group use the more delicate term "cuspidor" for the plainer official title.

The recently reclassified class of "Metallurgy" shows its highly advanced state as merited by its primary character and the immense amount of ingenuity that has gone into its development. Nothing could be more modern than its electro-thermal processes nor bolder than its gigantic stack and refining furnaces; nor more delicate than its processes for production of alloys. Here are temperatures reached undreamt of before this age and comparable to that on the surface of the sun, simulating conditions present in the convulsive processes of nature in the creation of primeval products.

An interesting class recently formed has the graphic title of "Medicines, Poisons and Cosmetics." This is, like a few others, a heterogeneous class of several distinct groups. Whatever implication of relationship between them is suggestive to the active imagination is not intended officially to exist. The poisonous ingredient, if any, in the medicine is obligated to cure and not to kill; the active principle in the second group is mainly for destruction; while the third is primarily for beautification of the person. Any device or preparation utilizable only for destruction of the human species and having no counteracting effect of preserving order or maintaining national security is considered to be without utility, and as such is not patentable. That is why the subclass of "Animal poisons" is not given its broadest biological meaning but is restricted to non-human beings, such as rodents, for example.

Butchering is a class that will surprise the uninitiated. It includes among its 45 subclasses such devices as machines for removing scales from fish, beheaders for fowls, instruments for making tough meat tender, in which the recalcitrant product is pounded or otherwise coerced into a state of edibility, and appliances for forming sausages into some sort of "linked sweetness," more officially termed "chain form."

Agriculture, our leading pursuit, is especially well represented. There are classes of "Harrows," "Plant Husbandry," "Planting," "Plows," "Harvesters," "Animal Husbandry," "Bee Culture" and "Dairy." The most ancient of implements is the sharpened stick for prodding the earth into productivity. For many millenniums its design remained unchanged. But to-day its modern prototype, the plow, and associated cultivators and implements require 245 subclasses, embracing almost 22,000 patents, to illustrate "the advance of the art."

The art probably the most "caviare to

the general" is that of "Chemistry-Carbon Compounds," with 173 subclasses. It abounds in weird names and stranger formulae. Dyes form its principal branch. The subclass 75 title, as an example, should be scanned lingeringly to avoid superficial interpretation of its import. It reads: "Diazo, azoxy, nitroso, azo, hydrazo—Trisazo—Diaminodiphenyl—Benzidine—Carboxylic." Peculiarly, the lines of division here follow more acceptably cleavages apprehended by commercial technicians, making the groupings more analogous than in the simpler arts.

The most formidable of the mechanical arts have not been touched upon. Textiles, printing, glass-making, threshers and harvesters, adding machines, metal working and many labor-saving devices are complicated beyond the imagination of the most advanced engineer of only a few generations ago. The directions of their advance and the significance of their performances could only be detailed by specialists in each branch. When it comes to electrical and chemical applications, with their adaptability to so many new services and their eerie capacities to achieve almost miraculous results, a different but equally difficult task is confronted.

Before 1868, less than two classes out of 22 were devoted to chemistry and none to electricity. In 1872, a single class of electricity was created out of 145. Today, about one third of the examining divisions specialize in the chemical and electrical arts.

The range of all the arts has not been indicated here. Things as simple as a hairpin or as ponderous as a cantilever bridge, and as various or antipodal as perfumes and explosives; dynamos and electric bulbs; dams and canals; tents and steel structures; rafts and submarines; refrigerators and furnaces; toy pistols and heavy ordnance; watch springs and newspaper printing presses; not to mention the processes for manufacturing insecticides and fertilizers; or for extracting metals or making dyes—all these subjects in the most refined differentiation are represented in the 5,000,000 U. S. and foreign patents, 35,000 subclasses and 300 main classes of the Patent Office files.

One may almost acquiesce in the conclusion that "there's nothing new under the sun" upon realization of what this vast literature contains as to man's accomplishments. Everything is there except the philosopher's stone and perpetual motion. And yet every year sees new accomplishments making obsolescent the wonders of a previous generation.

ARMY ANTS IN CALIFORNIA

By ARNOLD MALLIS
LOS ANGELES, CALIF.

ONLY an occasional lamp with its attendant circle of mellow light rippled the dark calm that pervaded over the college in Davis, California. On this July night, as on many previous nights, armed with a cyanide jar and with a vial of alcohol, ready to cope with giant long-horned beetles, huge electric-light bugs or with our special delight, winged ants, we commenced the rounds of the deserted campus. From pole to pole we maneuvered our pedal extremities, but in vain did we seek to appease the palate of our ever-clamoring cyanide jar. Finally a long line of ants scurrying across an illuminated area momentarily attracted us. A second glance, more careful than the first, did not return so barren. These could not be the ubiquitous Argentine ants, omnipresent in our walk, in our garden and in our sugar bowl; the hurried gait, the nervous antennae, the swift pace were all unlike them. And then we were electrified with the realization that here, before us, on this soporific agricultural campus, was the true sovereign of the jungle, the army ant, *Eciton*! Without delay, our dog-eared and ever-patient notebook commenced to delineate the peregrinations of these fascinating ants.

In a darkness that was dissipated by occasional lights, these nomadic meat-eating ants were to be seen moving along the curb on both sides of the street in trails that were some forty to fifty yards in length. Once, one trail was sighted that must have extended for more than one hundred yards. Diagonal and irregular trails connected the hurrying columns on both sides of the street. The ants moved for the most part in single file, and infrequently we would observe five or ten ants abreast, making a loose column some one or two inches in breadth. These columns would attenuate to files of single ants, which ultimately broke into scatterings of ants that hunted individually. In these trails, the ants marched in both directions. Some species of ants flow along like a drop of water down a pane of glass; other species of ants jerk along like a horse and cart in traffic; and the army ants, apparently the neurotics of the emmet world, presented a very agitated appearance as they traversed the terrain, this being augmented by the nervous movement of the antennae which constantly palpated the ground. Closer perusal of these reddish and greasy ants revealed the fact that the constantly vibrating antennae displayed a whirred effect not unlike an electric fan.

Moving across the ground at a rather animated pace, the ants individually covered a foot in approximately ten seconds, and an entire column would advance some seventy-five feet in one hour. Upon arriving at the head of an advancing column, we observed definite pioneers or trail blazers, and these, as soon as they were separated from the main body of the column, would turn about and run back approximately one inch, and then once again hasten to the trail blazing. Thus the head of the advancing column was not unlike an arrowhead, with a tip that advanced and sides which retreated.

Since reportedly these ants do not discern too closely the source of their meat—be it entomologist's ankle or grasshopper's genitalia!—the observer became

interested in finding what effect if any a 50 per cent. sugar solution would have upon them. When a one-half inch smear of this sugar solution was placed in their trail, it so definitely disconcerted them that they immediately turned back on both sides upon contacting it. They apparently did not detect the presence of the sugar solution until they ran into it with their antennae. Mere water when smeared across their trail would also disturb them, but after a few minutes they would cross this smear.

The predilection of these ants for concentrating in lighted areas was in all probability due to the great numbers of insects that were attracted here and upon which they preyed. In fact, the army ants returned nightly to certain lighted areas to capture their insect victims. With the ferocity of a wolf pack, the ants leaped upon any insect that moved within reach of their rapacious jaws. Individually or en masse, they would seize their prey and endeavor to drag it along, meanwhile curling the abdomen so as to sting. Once they were attached to a limb of their captive, only the most violent exertion on the part of their prospective victim could shake them from their grip. Any living creature that remained immobile was not molested, as for instance the click beetle that was ignored when it played possum and then was attacked immediately upon moving. A caterpillar that came into their path noticeably recoiled with each sting. Ground scavenger beetles, mayflies, water boatmen and crickets appeared to be favorites on their menu. Each night the ants could be found returning with their insect prey to a small slit between the grass turf and the curb. Yet strangely enough, when this same spot was probed during the day, no ants were to be seen.

Some of the ants were picked up and placed in a few glass vials. One of these vials was accidentally broken, and upon stoppering it with the palm of the hand, the ants commenced to bite rather severely, but they did not sting. These ants were then placed in a bell jar, and within a few hours they formed a complete moving circle around the sides of the jar. They continued to walk in single file and in twos for more than twenty-four hours. The following day many of the ants were quiescent. Some of the workers had various stages of immature young in their mandibles. One of the army ants, by means of her mandibles, grasped a larva just behind its so-called head region, the larva being held between the legs of the army ant so that the ventral side of the larva was next to the ventral side of the ant. Another of the captive army ants made repeated efforts to remove the larva from the care of the first army ant. These greasy-appearing ants spent much of their time licking one another's legs and antennae which they would do in a very deliberate manner. The ant being licked would placidly fold its legs, and lie on its side. Some of the ants that fell in an improvised moat recovered in one minute, after being placed on blotting paper, from a wetting of approximately twenty-two hours.

In this, our hour of need, we could neither borrow nor purloin a flashlight, and thus it was with some difficulty that the trails of these hurrying ants were followed when they traversed the dark expanses. While following one of these barely discernible trails along a curbstone, a sudden thickening of the single file of ants was noticed; this then enlarged itself into a very compact phalanx some two inches across. Obeying a hunch, and with various misgivings anent our future physical comfort, we plunged our fingers right into the center of this compact body, and like the celebrated Mr. Horner, extracted a plum,

the queen, a most rare and delectable specimen, indeed! Many workers were attached to various portions of the queen, and these, observing their decorum, made no attempt to sting us now or at any other time. Needless to say, when the queen and the workers were placed in a vial, the workers became very excited, particularly as displayed by the constant vibratile motion of their antennae. The workers by means of their mandibles commenced to excitedly rake the sluggish body of the queen, and even gave one the impression that they were biting her. Sluggish and quiescent, the greasy-appearing queen would rest her elongated and heavy abdomen upon the ground, meanwhile feebly twitching her antennae and tarsi. At other times the lubberly and matronly queen would vibrate her antennae, and with her tarsi feebly paw at some blotting paper. The workers were wont to attend her at all times, and with open mandibles they would feel the anal end of the queen as though they would appreciate an egg; however, this lady was never observed to partake of her queenly prerogative of laying an egg. The spectacle of numerous army ants parading and standing upon their comparatively huge queen while she rested upon her side was not without its humor; perched thus upon the queen, they would lick her body and appendages. Some alien larvae and pupae that the army ants had captured were piled upon a sponge adjacent to the queen. During the entire time that these ants were observed, they were never seen to make any attempt to eat these immature forms. This interesting queen, much to our regret, expired some five days after her capture. This may have been due to her being inadvertently submerged the previous day in a water moat; or to the environment, irksome to so regal a being, her soul departed.

On the second night after first sighting the army ants, while prowling about with our proboscis close to the ground, not unlike an aard-vark, we encountered a sight that held us spellbound for many hours thereafter, for there before us, spread out for a distance of ten feet along the curbstone, and barely perceptible in the darkness, were thousands of dead ants, many piled in heaps. Most of the ants strewn across this battlefield were blackish in color, and since the army ants are reddish, it could be roughly calculated that there were ten times as many dead black ants as there were dead red army ants. Imagine our surprise when we later ascertained that the dead black ants were those well-known aliens, the European pavement ants, *Tetramorium caespitum* (Linne). The combatants had evidently retired, and now the dead ants dominated the scene. A few living pavement ants were hauling the deceased and disabled from the nest, the latter revealing themselves by the feeble twitch of a leg or antenna.

Two days later, at 8:30 in the morning, when the sky was overcast, and a few drops fell, the army ants were observed on the march, and were seen to carry the immature forms and the adults of the pavement ants. That same evening we lowered our frame into the grass, stretched it in a horizontal position, adjusted our optical system accordingly, and now fortified with a flashlight, we focused same upon the scene of combat between the reddish army ants and the blackish pavement ants. If the number of dead scattered along the curbstone was any indication of the progress of this particular battle, then it must be stated that honors appeared to be evenly divided. The way of the red invader was strewn with thorns, for the blackish army ants would "gang up" in twos to sevens upon an army ant, seize her appendages and then stretch them to all points of the compass. Some pavement ants were car-

rying disabled army ants from the field of honor only to dump them unceremoniously upon the curbstone, or upon the heaps of ant-dead. How fiercely the battle had raged could be readily attested by the great number of ant mounds distributed along the water pipe.

As the evening grew older, some of the savage army ants were observed carrying the captured larvae and pupae between their legs so that the venters of both adjoined; a few of the ants conveyed callows. One army ant was bearing an adult pavement ant that was apparently dead; it lacked antennae, and one node of its petiole was practically separated from the other node. It appeared as though every other reddish army ant carried some form of pavement ant.

At approximately eleven o'clock that same evening, some two and one half hours after our first observations, we returned to the water pipe along the curb to once again survey the scene of the military engagement. Hostilities had noticeably subsided; here and there a red army ant and a black pavement ant were still engaged in mortal combat. No longer having to concern themselves with their enemy, the black pavement ants were now engaged in removing from the nest the dead and dying combatants, whether red or black.

What of the army ants and the living booty that they had plundered from the nest of the pavement ants? Following these we soon came upon a strange sight but a few feet removed from the battlefield. On each side of a vertical groove in the curbstone hundreds of army ants were grouped in an irregular body three eighths of an inch wide and two to four inches long. The mass of army ants on either side of the groove, immobile except for their moving antennae, grasped the larvae and pupae of the pavement ants in their mandibles. Other army ants moved in a cleared furrow between these living walls. Evidently this assemblage about the groove was a temporary storage ground for the captured pavement ants. Some five feet further along the curbstone around a similar groove, pupae and larvae were assembled in a mound upon which the army ants were gathered; two similar accumulations were encountered within the next eleven feet. A number of small black mites were present wherever the army ants were thus aggregated. Having duly captured their victims, the army ants were engaged in conveying their captives to the other side of the street.

One and one half hours later, but one cache was to be found, and this one some fifteen feet from the scene of the battlefield. Additional observations at the site of the battle disclosed the fact that the blackish pavement ants would not hesitate to hasten to the attack, many of them carrying off army ants by their own individual efforts. Bulldog-like in their tenacity and valiant in the face of their advancing foe, they would move forward to grapple with the fierce army ant. Quickly would they dart and endeavor to seize the long mandibles of the army ant. Failing this they would grasp a limb. The army ants would endeavor to sting, and then both ants would coil their abdomens as though they were applying their abdominal stilettos. At times, in the ensuing melee, four to five army ants would rush to the aid of their embattled sister, and would then seize various appendages of the pavement ant. One army ant was observed to clamber upon a pavement ant, place its mandibles over the neck region of the pavement ant, the latter then being rendered *hors de combat*. An innocent bystander, *Dorymyrmex pyramicus* (Roger), a common dark ant hereabouts, concerned with other matters, would hastily scurry from the path of any army ant it inadvertently contacted.

Now the war had risen to the very heights of fury! The killing was done with great dispatch and quite neatly, with none of your crimson gore to mar the martial scene. Here, a black pavement ant, pegged out like a circus tent, its appendages taut as violin strings, would be in the center of a circle of tugging red army ants; adjacent, a red army ant, the hub of an encircling body of black pavement ants, was being drawn and quartered in the most respected manner of the Inquisition. Two pavement ants made fast to an army ant, one seizing the mandibles, the other the hind femur; fighting savagely, desperately, the red army ant finally wrenched itself free. There, an army ant unconsciously displayed her warlike prowess; her black victim fastened to her limb, refusing to yield even to Death! Locked in combat, the warring individuals would strive to seize the mandibles, a vital hold; at one and the same time they would curl their abdomens beneath them, evidently for leverage, for protection and in order to sting.

The army ants continued pouring their red hordes into the nest; and the pavement ants fought valiantly and unflinchingly against the invaders. But despite this, the army ants emerged triumphant from the nest bearing the fat larvae and pupae of the pavement ants in a constant conquering stream. Yet, individually, in ant-for-ant fashion, the black pavement ants appeared quite capable of coping with the red army ants. It must have been sheer numbers, the vast inpouring of the army ants into the nest, which made it possible for them to overpower the pavement ants. In defeat, the army ants would appear entirely exhausted, disclosing their debility by feeble twitch of leg or antenna. This savage invasion and implacable war raged for three nights, having undoubtedly commenced several days previous to our first observations.

The following night there was no evidence of fighting, but two mounds were found that contained several hundred larvae and pupae of the pavement ants. Both caches were well attended by the army ants, and two crowded trails led to these mounds. The army ants were then engaged in carrying the larvae and pupae into the crevice between the curb and turf which appeared to be a provisional nesting site.

On the next evening the army ants again emerged from the area between the turf and the curb, a crevice that had been closely inspected during the afternoon, and which was at that time barren of army ants. Three caches were seen, each of which was covered by several hundred army ants. The immature forms of pavement ants were to be seen in one mound. When this was disturbed by flashlight, the army ants commenced to remove the young, carrying them between their legs in the previously described manner. Whenever annoyed by the flashlight or by being breathed upon, the army ants would raise their bodies so that they inclined sharply forward, or were almost vertical; the abdomens would be curled beneath as though they were sitting on them, the front and middle legs would be rigid, the hind legs bent, the mandibles widely opened, and the quivering antennae would inquire outwards.

Coincidental with the marching of the army ants was the emergence of thousands of tiny thief ants, *Solenopsis molesta validiuscula* Emery, the workers, the males and the queens. Intense was their excitement, for the nuptial rites were to be performed, the mating flight consummated. No respecters of holy matrimony, those coarse barbarians, the army ants, would seize the brides

and grooms, and carrying them by the side, they would hustle them off to serve as the "piece de résistance" in some ant banquet. Not one to stand idly by while such sacrilege was committed, the pale yellowish tiny thief ants would seize the army ants by the legs, mandibles and terminal portions of the abdomen; the latter evidenced their displeasure by vigorously curling their abdomens and endeavoring to sting. In this case, as with the pavement ants, resistance was entirely futile.

For seven nights we had been on the trail of these marauding army ants; on the eighth night they were gone, apparently having vanished into thin air. Approximately one month later, we once again blundered upon them, this time in broad daylight, some fifty feet from the area where we had first made their acquaintance. They were marching over a somewhat moistened and shaded area, and apparently had just pillaged a nest, for they were conveying larvae and pupae which appeared very similar to those of *Tapinoma sessile* Say, the odorous house ant. We sighted them in the morning some two days later, in the same locality, and this was our last tryst for many months to come. Although the army ants had gone, they had left in their place an unsolved enigma, namely, could they "lick" the Argentine ants, emmet champions of the Davis campus, and omnipotent conquerors of all ants who dared resist their roll of empire? We had seen the army ants vanquish foes who had opposed them with crushing mandibles and darting stings; we had seen the Argentine ants dismember their opponents, limb by limb. In a clash between the army ants and the Argentine ants, upon whom would the gambling gentry place their odds?

Nine months followed each other into oblivion, and at 8:30 in the evening of April, 1936, our respective orbits crossed once again. At the base of a lamp post, that red scourge, the army ants, were busily engaged in overwhelming carabids of a small size. With the expenditure of much energy and the accomplishment of little progress, the army ants were occupied in dragging their victims away from the lamp post, and were hindered by some of their sisters who believed the prey should go in the contrary direction. The army ants then occupied all the area about the base of the lamp post. Upon returning at ten o'clock the same evening, it soon became evident that the "status quo" had been radically altered. The army ants now occupied but one half the area about the base of the lamp post; the Argentine ants held the other half. For the first time the army ants were on the defensive, and the Argentine ants had decided to contest their rights to the hunting grounds at the base of the post. A rough triangle of army ants, with the apex foremost, faced the Argentine ants, the number of ants in this triangle varying from time to time from twenty-five to fifty ants. Now that the army ants were in battle formation, they were immobile, watchful and expectant, with their antennae extended at right angles to their heads. Behind this triangle stood other army ants in the peculiar position previously described; abdomen curled beneath, hind legs bent, front and middle legs stiff and rigid, the body proper inclining forward at a forty-five degree angle, there being some five or six ants in this strange position of watchful waiting. For a few inches outside the apex of the guardian triangle, a "no man's land" was to be found in which army ants were embattled with the Argentine ants in ant-for-ant combat. The Argentine ants utilized the usual attack, pulling and tugging at the appendages of the army ants. At times, an Argentine ant would penetrate this guardian triangle that protected the orderly retreat of the

army ants. Sometimes this would cause practically no commotion, but at other times the army ants would rush savagely for the Argentine ant. Slowly the army ants retreated from the base of the lamp post into the adjacent grass, protecting their rear-guard with the redoubtable triangle. And behind this protecting triangle, the army ants were busily engaged in dragging carabids between the grass and the concrete base of the lamp post. At 11:30 that same evening the army ants had practically disappeared from the base, and were now marching into the grass. It was thus that the Argentine ants met the challenge.

Individual army ants when removed from their ravaging armies appeared to be much more mild in temperament. On placing seven army ants together with five Argentine ants in one vial, it was observed that the two species were anxious to avoid each other. Finally one of the Argentine ants seized an army ant by the tarsus of the left hind leg. The army ant while being hurled and dragged about offered no resistance to the Argentine ant; in fact, the only effort the army ant made to escape this persecution was to brace itself with its thick antennal scapes against the glass surface. The other army ants in the vial made no effort to aid their sister in distress, even when close to her. It is difficult to understand why the tormented army ant made no effort to resist, even when it practically had its mandibles around the leg of the Argentine ant. In time the Argentine ant released its hold on the army ant, and then the latter appeared to be in an exhausted and sorry state.

Not content with pillaging the nests of their kind, the army ants, like their ubiquitous cousins farther south, have in rare instances made a nuisance of themselves by invading homes in Sacramento. In all probability, it is only their lack of numbers that deprives them of the respect that their tropical sisters command.

And with this, we bring down the curtain upon a glimpse of ravaging, pillaging, nomadic ants, intriguing six-legged creatures whose limbs are more properly at home in unspoiled equatorial forests and jungles than in the effete Kentucky grass of an agricultural college campus.

A SCIENTIST IN MOSCOW

By Dr. DEAN BURK

WASHINGTON, D. C.

Is there a characteristic Soviet science and scientific spirit? Although the man of science is in many ways the same the world over, it is important to consider him in relation to his fellow-men, whose lives he constantly changes, and to regard him as a member of a given social organism which has attained a particular state of complexity and knowledge. The fact that the background of Russian science, and of Russian culture in general, has been so distinctly different from that of Western countries makes the present rapid scientific development in the Soviet Union an interesting subject to consider from many points of view. On the basis of recent visits to the U. S. S. R. and as an experimental worker in a Moscow laboratory, I shall describe certain aspects of Soviet science and of scientific life as I saw it and took part in it.

Since the revolution of 1917 there has been a ten-fold expansion in the number of scientific institutions, personnel and output of experimental work. A similar but less marked development took place in the United States during the first quarter of the present century. The exceptionally rapid increase of scientific work in Russia has been made possible by a research budget which undoubtedly comprises a proportion of national income as large as or larger than that of any other country. Because of the short time-scale over which this increase has occurred, many laboratories have the atmosphere of a pioneer settlement, with its lustiness and confusion, projects in various stages of construction and general overcrowding. I was walking through one such laboratory with a prominent young chemist, and casually remarked on the large number of workers. "Yes," he said, with a smile, "and confess that you are wondering just what they are all doing."

The large influx of scientific workers may be explained in part by the widespread public interest in science. Science has been characterized by some as the new national religion, and, in so far as the people believe that it is the basis of their present and future well-being, this description is apt. It was upon the occasion of a visit to Russia in 1935, to attend the Physiological Congress, that I first became aware of how general has become the replacement of a belief in God by a belief in man and science. Through the newspapers, which devoted more than half of their space to reporting this huge international gathering, all the big names and events of the congress were made known to the man and woman in the street. For a time, it was surprising to find that many people in walks of life far removed from the scientific were familiar with the leading Soviet scientists, and, in instances, with details of their particular accomplishments.

When the congress as a whole traveled out from Leningrad to Peterhof twenty miles away, in a procession of four hundred automobiles, the entire route was lined with people waving handkerchiefs, and at one point soldiers threw their caps into the air. On another excursion made by a smaller party to the large recreation park in Moscow, a similar spontaneous reception was afforded at the gate by a cheering crowd, which, of its own accord, in a spirit of self-government often encountered, formed a gangway to let the visitors enter. Inside the park, an open-air theater audience of twenty thousand spectators rose to its feet to greet the congress members as they filed in to their seats. This friendly, albeit embarrassing,

demonstration of feeling to the foreign scientists by the general populace reflects, in some measure, the nature and extent of the popularity of science in Russia to-day.

II

At the head of the scientific system of the Soviet Union is the Academy of Sciences, founded by Peter the Great about 1725. After the revolution the academy was taken over by the new government and in 1934 moved from Leningrad to the capital at Moscow. This change was made necessary by the significant position attained by the academy in the planning of the industrial and technological development of the country. The resulting upheaval accounts for much of the disorganization encountered in the Moscow laboratories. Plans for a group of new buildings have been prepared but will require some years for execution *in extenso*. In the meantime, the academy's headquarters have been established in a former palace in the district of the proposed new buildings, and its work is carried on in about a score of institutes nearby. In the past there were forty academicians, according to the French tradition, which Peter the Great wished to emulate; now there are more than ninety.

The academy, working with the Soviet State Planning Commission (Gosplan), is the center for directing the scientific activities of the Union. Through various committees, the economic and industrial needs of the country as a whole are studied, and each year a plan of research is drawn up and apportioned to the different institutes. In the words of Karl T. Compton, president of the Massachusetts Institute of Technology and chairman of the former American Science Advisory Board, "the Academy of Sciences of Moscow has been called upon to aid the government in organizing the great system of research institutes recently created throughout the country and now in progress of doing some of the finest and most progressive scientific work to be found anywhere in the world."

The internal organization of the academy institute at which I worked is typical of that of most places of work in the Soviet Union, whether factory, office, hospital, university or collective farm. A maximum of self-government is achieved in any of these institutions through a system of *triple control* by what is commonly known as the "Triangle," which consists of a member of the administration, the local secretary of the Party and one person from the social unit or trade union. I had excellent opportunities to watch the operation of this characteristically Soviet system of triple control, and, in one particular instance, to follow the course of development of an intricate case for a period of nearly a month as it drew to a climax. A scientific investigation had been pursued by a certain group of workers for some six months with diligence but, as gradually and then finally became evident to fellow-workers around them, with inadequate judgment. In default of immediate correction on the part of the scientific director, the matter was taken up, after much private discussion, by the social group, and finally by the Party, to which the scientific director eventually admitted full personal responsibility for undue laxity.

Various individual matters are handled through the Triangle, such as redress in case of claimed inadequate remuneration or position. It is the great merit of the system of triple control that, however much it might seem upon first consideration to be a case of two cooks too many, it does provide the individual who desires some adjustment with a means of social leverage to bring forward his claims.

THE BIOLOGICAL INSTITUTE OF THE ACADEMY OF SCIENCES, DECORATED FOR YOUTH DAY.

The system of triple control succeeds in providing a good average of objective judgment, with a maximum of dignity, for all parties concerned. Of course, it operates more as a balancing force than executively; for instance, the scientific director generally determines the salary scales and budget allowances within his institute, subject, however, to the possible readjustment indicated.

III

The opinions and wishes of the workers as a whole are made known at innumerable meetings of the political, social and scientific groupings, at several of which I was an interested spectator. Although quite frequent, these meetings were always well attended, not only because participation was expected, but because Russians enjoy talking endlessly over problems real and imaginary, and are perhaps never happier than when they have transferred one of these problems from the material world into their heads. Often a long table was set with plates of cookies, apples and candies, and enormous quantities of tea were consumed, for which literally buckets of hot water were carried in. Emphasis was equally divided, in talks describing the progress of work in the laboratory, between outspoken but friendly criticism and due praise. Following this, the discussion would often turn to more general topics and eventually to the world-wide political situation. I remember in one particular talk that a professor pointed out in connection with discussion of the Physiological Congress that, whereas before the revolution not more than a score of people in the whole of Russia could have taken part in such a congress, one hundred and fifty of the five hundred papers of the congress had been given by Russians, in widely different fields, and, incidentally, in the languages of the visiting foreigners.

At less frequent intervals there were joint meetings of several institutes, at which it was the custom to elect or to appoint a dozen or more temporary vice-chairmen, who would individually and with applause take places of honor on the platform. At one joint meeting which I attended, our laboratory dishwasher sat

THE LOCAL SECRETARY OF THE PARTY

IN AN ACADEMY INSTITUTE DEVOTES THE USUAL SIX HOURS PER DAY TO LABORATORY WORK.

in this capacity by the side of a venerable academician. Each time that she caught the eye of some one she knew in the audience she would blush and appear very self-conscious; she was unmistakably delighted at the honor of being elected. The shared dignity of all classes of workers, in and out of science, was impressive to observe. At a tea-table discussion one day, some one had said to me, "Our ideal is not so much democracy as humanism." I should mention that the dishwasher was a "udarnik," which means in American that, though only a dishwasher, she was an excellent dishwasher.

Upon special occasions, such as nights before May Day or November Seventh, meetings of the entire academy would be held in the large Red Army Hall, which, like the Smolny Institute, the State House in Leningrad, was formerly a school for *jeunes filles*. It was at one of these celebrations that I heard the education of Oxford and Cambridge described in all seriousness as medieval and semi-religious, and the modern Soviet universities compared with them to great advantage. The speaker, a man of seventy, remarked, with a look to his audience for approval, "Even an old dog like myself can change with the times." During the evening there were eight speeches, each fifteen to twenty minutes long, listened to attentively from beginning to end by all, including eighty-eight year old Professor Karpinsky, the late president of the academy. The speakers included, apart from scientists, a well-known author and publicist, the head of Gosplan, the second ranking officer of the Red Army, and another Red Army officer who had just returned from France and who gave a long account of his visit and conversations with French generals. An important member of the Party talked for forty-five minutes, without reference to science, on the history, theory, practice and achievements of the U. S. S. R. since 1917. After an intermission for refreshments, an early one-act play of Gorki was presented, followed by music and a ballet by men of the Red Army, until past one o'clock. During the speeches, the mere mention of a well-known name brought forth tremendous handclapping, accompanied, upon appropriate signal, by music from a loud brass band concealed in an alcove. Each speaker mentioned Stalin, Kaganovitch or Molotov at least once (brass! without signal!).

At this meeting, and at the smaller ones also, I found it difficult to determine just how seriously the older scientists of pre-revolutionary days regarded this outward form and expression of a spirit not unfamiliar in America among other classes of people. I was convinced, however, that in their every-day work the older scientists on the whole yield to none in being active and sincere proponents of the new system and philosophy of their régime; most are unquestionably leaders in the procession, if they are in it at all.

At the close of the meeting I sounded one of my friends, a younger professor of forty, as to what he thought of all the speechifying, and he confessed that ah, yes! the Russians *did* have a natural fondness for long speeches and plenty of them, even to liking to hear the same things over and over and over again. He recalled that during the preparations for the Physiological Congress he had attended committee meetings twice a week for six months before the event, but that beyond discussion nothing was done until three or four weeks beforehand. With good-natured appreciation, he freely cited other instances of the Russian preference to look upon the big ultimate problems of the future rather than to attack the immediate task on hand. As a Soviet doctor explained, when it was suggested to him that screens be provided for the doors and windows of a hospital filled with flies, they were not troubling about screens now, because when the time came, they planned to exterminate the flies both inside and out!

The capacity of Russians not to worry —not to "get in a stew"—gives them a quiet self-assurance which I learned to admire. As the English are traditionally calmer than the Americans, so the Russians seemed even calmer and quieter than the English. I found too, that, con-

SCIENTISTS ALL

(STANDING) A TARTAR, A CALIFORNIAN; (SEATED) A "UDARNIK," A COSSACK, AND A MUSCOVITE.

ONE OF A GROUP OF BUILDINGS HOUSING SIX THOUSAND STUDENTS IN NORTH MOSCOW.

trary to a casual opinion I had formed before my visits, they have a decided ability not only to laugh, but to laugh at themselves, with a characteristic childlike jollity. Everybody in the laboratory was amused when I read to them from a book in English which explained with some confidence that "when a Rusisan says 'right away' he means 'tomorrow,' and when he says 'tomorrow' he means 'never.'" Of their own accord, thereafter, they never failed to distinguish for me between an American to-morrow and a Russian to-morrow, in connection with things actually to be done or actually not to be done. From time to time I showed them pictures of my small daughter, selecting those which seemed to give her rather a Russian appearance, even though, in fact, she was not in the slightest of that blood. They, too, thought that she looked like a Russian baby, until one day some one happened to catch sight of some of the photos I had not exhibited, and exclaimed, "Why, he has been showing us all the ugly ones!" Once during a street-car jam at midnight, on the Nevsky Prospect in Leningrad, thirty trams in line were held up by an auto stalled in collision with the foremost one. An ambulance had departed with the injured within five minutes of the accident, but after a wait of more than forty-five minutes, I overheard one comrade in the crowd remark with gusto to another that evidently they were telegraphing to Stalin in Moscow to obtain permission to remove the auto from the tracks. This incident is suggestive of a prevailing Russian quip that the cure for bureaucracy is more bureaucracy.

IV

The day at the laboratory started at nine, when the udarniks (best workers) usually arrived, with others continuing

to put in appearance up until ten o'clock. Consistent with the planning element found in so much of Soviet life, a great deal of the routine work was mapped out on a day-to-day basis well in advance, usually by periods of three months. For instance, when I wanted some Kjeldahl analyses performed, the analyst would often look at her chart and announce a date already arranged for such work. (Dates instead of names of days are used universally, and in the Soviet weeks of six days, "rest-days" come on the sixth, twelfth, eighteenth, twenty-fourth and thirtieth of each month). In the higher positions, although the research worker has certain problems allotted to him in the general plan drawn up by the department for the year's work, and divided by the laboratory administration somewhat into quarterly quotas, there is in practice little undue interference with the execution of his work.

At two o'clock the main meal of the day is taken. Each institute commonly has its separate dining hall, and there is yet another reserved for the use of those of full professorial rank. At the latter the food was somewhat better, and more tastefully served. These main meals cost from one and a half to three rubles. In general, I found the food nutritious, and, although rather heavy in starches, not without variety according to European standards. Russians of all classes have notably a "carbohydrate" physique, tending to be short, stocky and solid. On each dining table was a plate piled high with slices of several kinds of bread, and my companions often remarked that I ought to eat more bread and drink less water. After lunch the bustle of the morning was not always regained, and frequently one came across huddles of a half dozen or more people deep in discussion of both work and, inevitably, personalities. At four, except in the event of a general meeting, or a language class, the workers would begin to leave. Overtime work was common, as in all scientific laboratories, but seldom regular save on the part of some of those housed at the institute, mainly bachelors. In the newer buildings, many of the scientific staff live in apartments in the institutes. Although this arrangement is not uncommon in European laboratories, the idea has been frequently put into practice in the U. S. S. R.

After a six- or seven-hour day at the laboratory, which is standard for most kinds of urban work, an average of one to

A GAME OF CHESS AT THE LABORATORY.

THE ACADEMICIAN-DIRECTOR OF THE LABORATORY (LEFT) DELIVERED THE FIRST SPEECH AT THE OPENING SESSION OF THE SUPREME SOVIET, JANUARY, 1938.

A GROUP OF LABORATORY WORKERS.

THE VISITOR FROM A FOREIGN LABORATORY IS SURPRISED AT THE LARGE NUMBER OF WOMEN SCIENTIFIC WORKERS.

three hours might be spent in some form of social endeavor. It is generally expected that every one, in his free time, will undertake some social service. This is an unwritten obligation and a matter of popular ethics. As in each factory or office, there is a committee at the academy to take charge of these activities and to adjust the distribution of various social tasks among the workers. Health, vacations, sports, theater tickets and language classes are among matters which receive this voluntary attention. It is quite common for older, more experienced workers to give instruction to those under them. During my stay at the laboratory one man was given the temporary, not unpleasant task of seeing that all went well with me. He was especially qualified to do this because, unknowingly, we had been fellow-students in early college days at Berkeley fifteen years before; he has now been permanently settled in the U. S. S. R. for ten years, with a Russian wife.

The chief social duty of the academicians and professors is to report and explain to other workers, both personally and through the press, concerning scientific progress and its relation to their work and lives. At five or six huge gatherings a year, held in the Palace of Culture, scientists of world renown, beloved and respected, tell of the developments of knowledge in their particular fields of activity to audiences composed mainly of factory workers—much as John Tyndall did in England in the nineteenth century during his long directorship of the Royal Institution.

The organization of foreign language classes is an essential feature of laboratory life. These classes are held after work at the institutes, and became especially popular after the Physiological Congress. During my stay I was invited

to take an active part in the English class. Much use was made of stories written in the eight hundred and fifty words of Ogden's "Basic English," and also of Mrs. Ivy Litvinov's widely distributed English grammar explained in the Basic Russian which she has created. We would start the lessons by asking and answering formal questions in English, and this would usually develop into an animated, if somewhat hesitant, conversation about life in Russia and in America. Once we discussed the November Seventh parade through the Red Square, and it developed that some of them had not marched. I told them of a remark that had been made to me about "only the babies and old ones left behind" and they volunteered, "Yes, and the lazy ones, too." We talked about the role of women in America—did many work in science?—did most ever do anything more than be stenographers or secretaries?—did they ever really run things? One girl, who admitted to their all being frankly envious of the mechanical level of civilization attained in America, said that she pitied American women, and spoke with pride of the absolute political and economic equality which she said was now established between men and women in the U. S. S. R. I replied, "Yes, but think of how many American women have homes of more than one room to live in," and was facetiously accused of being a fascist. I decided, from our various conversations, that most Russian scientists, even those generally well-informed, find it difficult to understand the nature of the opposition to the U. S. S. R. existing in other countries, or to grasp the idea of the "Red Scare" in the concrete and what it has meant in terms of circulation for foreign newspapers of another color. During my laboratory stay, I was asked many times by scientists, of all ranks, whether I had been "commissioned" to come to do my research—whether, in other words, I had, for some reason not readily evident to them, been "sent." It was a pleasure and reassuring to me to note first their interest in this point and second their immediate and invariable approval upon being told that the initiative had been entirely my own. Evi-

THE STUDY OF CONDITIONED REFLEXES

IN A HOSPITAL FOR (FOUR HUNDRED) PROBLEM CHILDREN, LENINGRAD. SALIVATION OCCURS ON ONE SIDE OF THE MOUTH ONLY, UPON INGESTION OF SUGARED CRANBERRY AND FLASHING OF PROPER LIGHT SIGNAL (BLUE LIGHT, LEFT SIDE, GIRL; RED LIGHT, RIGHT SIDE, BOY).

BIOCHEMICAL LABORATORY IN OLD PAVLOV INSTITUTE GROUNDS IN LENINGRAD.

dently something in the internal structure of their society and in the psychology resulting therefrom heightened the importance of, and gave special color to, this piece of information.

It is easy to find an opponent for a game of chess in Russia. Chess in Russia is to some extent what baseball and football are in America. Recreation rooms invariably have chess boards inlaid in the tables, and chess sets in store windows are almost as common as women's hats here. One morning at ten, after discussing experiments, the seventy-eight year old academician who directed our institute suggested a game of chess. He warned me that he had been playing for sixty-six years. We had three games, lasting for three hours, and of which he won two. We ended by congratulating each other upon the quality of our play. This interlude upon the part of a busy director, famed for classic experiments performed thirty to forty years ago, and now responsible for several institutes, was as pleasant as it was unexpected. On his visits to the laboratory, every other day or so, this academician-director shook hands with all personnel he met, from top to bottom in rank, and, in accordance with old Russian custom, only Christian names, first and second together, were used in mutual greetings and conversation. (I have no second name, but they had said, "that doesn't matter, what was your father's first name?" and upon being told, they replied, "Well, then you are Dean Fredericovitch, and your daughter is Diana Deanovna.") At the present moment of writing, the academician-director referred to has had the honor of delivering the first speech at the first session of the Supreme Soviet of the Union elected last month under the new constitution, and of presiding on the rostrum during the nomination and election of the president of this parliament. In addition to being a president of the Mendeleyev Chemical Society and chairman of the All-Union Association of workers in Science and Technics (Varnitso), he has been a member of the Moscow Soviet several times previously, a member of the Council of

the People's Commissariat of Heavy Industry, and a member of the All-Russian Central Executive Committee.

In England and America appreciation of the fine arts is high among scientists taken as a group, but the Russian scientists do not seem, contrary opinions expressed to me by some of them notwithstanding, to indulge to the same relative extent in the cultural life being built up around them; for one thing, they are too occupied with their more-than-average responsibilities. Their places in the concert halls, galleries and theaters are taken by the other worker types. Members of the Red Army are conspicuous at the very best theaters, where they receive preference of tickets and enjoy especially favorable rates. At the academy, nevertheless, there is an individual whose duty it is to obtain such seats as are desired by its workers. Like most institutions, it maintains a fund, rather large, for paying for various social activities, including part of the price of theater tickets, up to as much as 50 per cent. in the case of the least well-paid workers, and also, on the other hand, as a reward in the case of the very best workers; the theater always gets the full price, though the worker may seldom pay it, unless he deals with the box office directly, as he may if he wishes. I attended many performances. The audiences were mostly quiet, often tense and completely absorbed. Twelfth Night was presented as a roaring comedy. Less attention was given to the truly sad aspects of Malvolio than by the Stratford-on-Avon players, and much play to Maria, the clown, Sir Toby and Sir Andrew. The people in the audience, gripped throughout, leaned forward in their seats when, in the final scene, Sebastian ran in with sword in hand, clearing up all situations and difficulties, and, with the relaxing of the tension, cheered just like any cinema crowd when the hero finally arrives. "Pickwick Papers" was presented at the First Moscow Art Theater in eight long

HEADQUARTERS OF NEW PAVLOV INSTITUTE
OUTSIDE LENINGRAD (KOLTUSHI), CONTAINING A MAZE OF CONDITIONED-REFLEX CHAMBERS.

FOR SCIENCE TO PROSPECT. A FARM NEAR MOSCOW.

scenes which followed closely the original drawings of Phiz.

V

I estimated that the salary spread in the institute at the academy at which I worked, and in the larger Soviet universities generally, was probably slightly wider than in similar institutions in the United States. The salaries of scientists of some experience, men in their early thirties, and not including heads of laboratories, average in Moscow perhaps eight hundred roubles a month. It is not easy to estimate the standard of living as compared to American standards, but, in general, the eight hundred rouble salary would provide a three-room apartment, a part-time maid and a vacation in the Crimea every year or so. Workers with less experience, but with some previous training of a formal nature, receive from two hundred and fifty roubles a month upwards. Academicians, laboratory heads and professors of full rank commonly receive one to two thousand roubles a month, and are often provided with cars in addition to their salary, especially when their official duties require their presence in several institutions. Owing to the shortage of leaders, ranking scientists often hold two or three positions, directing and teaching. Many of them still work in both Leningrad and Moscow, commuting back and forth, on overnight trips, every few weeks during the academic season.

The average age of the scientific workers is quite low, about thirty, I should judge. The visitor from a foreign laboratory is surprised at the large proportion of women workers, about 30 to 40 per cent. In one well-known laboratory in Leningrad which I visited, eighty-one of the ninety-two workers happened to be women. The number of women directors of laboratories or sections is proportionately smaller, but without doubt greater than in Western countries. Of course, there has been an established tradition

of Russian women working outside the home, not only in the field, but also in a variety of intellectual pursuits, particularly in the social services and in politics, and this has been greatly extended under the new system.

As in the laboratories of other countries, some research workers are turning out work of high quality, many are not. It must be said for the present that a distinctly low critical standard is generally regarded to prevail in Soviet science taken as a whole. Naturally there are many individual laboratories where the highest standards exist, but these do not compensate for the others, though doubtless they merit the most attention. A series of related causes has contributed to this state of affairs: the shortage of first-class scientists for the training of personnel; the lack of up-to-date laboratory equipment; the necessary emphasis on results of more immediate application; and, perhaps most important of all, the isolation of the last twenty years, with the accompanying inadequate interchange of publications and criticism with other countries. It is worth remembering, too, that a large proportion of the lower ranks of scientific workers, as of the people on the street, are peasant in origin and outlook, and that decades will be required to alter and remove this background. The tempo of life in the U. S. S. R., increasing rapidly on a relative scale, is still geared on an absolute basis to about one third the level existing in the most advanced Western countries; the same slow tempo is known to have prevailed during the early stages of industrialism in England, Germany and other countries not much more than a century ago.

There is no lag, however, in the application of science to large-scale operation, and this often in a manner to cause envy among *confrères* in other countries. It is a factor of great importance in certain studies, especially in the sciences related to agriculture, where outstanding work has been carried on, particularly in genetics, in terms of square miles.

With the development of the light industries the problem of laboratory equip-

PHYSIOLOGISTS ON THE WAY TO LENINGRAD.

THE CAPTAIN (CENTER, CLOSELY-SHAVEN) OF A SOVIET BOAT PLYING FROM LONDON TELLS DELEGATES TO THE FIFTEENTH INTERNATIONAL PHYSIOLOGICAL CONGRESS WHAT TO EXPECT UPON ARRIVAL IN LENINGRAD.

THE KREMLIN, WITH NEW BRIDGE UNDER CONSTRUCTION

TO ACCOMMODATE SHIPS FROM THE VOLGA-MOSCOW CANAL. THE CONCLUDING BANQUET OF THE PHYSIOLOGICAL CONGRESS WAS HELD IN THE BUILDING AT EXTREME UPPER LEFT.

ment is being remedied. In the past the more important instruments had to be imported at almost prohibitive expense to the country.

The state of isolation is beginning to receive attention, both internally and abroad. At the Physiological Congress visiting delegates expressed hopes that the Soviet government would, in the near future, provide a considerable sum to give young scientific workers the opportunity to study in the laboratories of other countries. The first post-revolutionary scientific congress of note to be held in the Soviet Union did not occur until 1930, when the International Society of Soil Science met in Leningrad and Moscow, and followed this with an extended tour of the country. The Mendeleyev Chemical Congress met a few years later. The first big international congress was the Physiological Congress, inaugurated by Pavlov in the palace of the old Duma, and attended by some twelve hundred foreign scientists. It opened the eyes of the Russians and Russian scientists to the necessity of their keeping in touch with the outside world. Unfortunately, other trends within the country have for the time being prevented much accomplishment here. The scheduled International Genetics Congress was cancelled somewhat over a year ago; on the other hand, however, the International Geological Congress met in Russia last summer under auspices nearly as favorable, if not as elaborate, as those of the Physiological Congress.

VI

In weighing the achievements of Soviet Russia and evaluating its scientific life, it is more profitable and interesting to compare new and old Russia, rather than new Russia and modern America, and it is important to do so on a humanistic as well as materialistic basis. I was told many times, literally and in substance, "You Americans and English are busi-

ness people. We enjoy life." The thick throngs leisurely promenading the Nevsky Prospect, the Red Square and other similar thoroughfares every summer and fall evening from six until far past midnight are a memorable sight.

On November Seventh, the anniversary of the revolution, one thousand academy workers, including academicians and professors of three score years and more, march with a million and a half of the populace in the parade through the Red Square. At such a time one of them said to me, "You will never see anything like it." The academy group met at its headquarters some three miles away, walked briskly for the first two miles, and then was forced to slow up upon approaching the Kremlin, as processions from a dozen or more routes converged at the entrance. The sea of banners suggested some medieval pageant. Now and then during the march small impromptu groups of children and young people, in fancy dress and often singing and dancing, cut across the line on some route of their own inclination. One such group of small boys sang lustily the popular march from the Soviet film, "Jolly Fellows," with most, but not all, of its sharps and flats. "Would Stalin still be there?" was the question every one was asking as time for entering the Square drew near. If not, would Kaganovitch, Molotov or Voroshilov? Yes, at two o'clock, after four hours of parade, and three more yet to come, all four leaders were still there, gayly waving back from the reviewing stand in reply to the cheers of the marchers moving past, one hundred abreast in ten files of ten persons each.

That night, after the parade, the illuminated red flag waving ever so slowly over the Kremlin in the cold crisp winter air, without visible means of support, looked very small but very firm at its great height. It seemed as imperturbable, in its one sixth of the globe, as the four lions of Trafalgar Square in an even greater empire.

It is necessary to enter with some sympathy into this Russian atmosphere, with its interesting past, its present humming and a future ever in the air, to realize even the obvious features of a society based so distinctly upon a scientific philosophy—a society wherein it is so generally believed that the more science develops, and is allowed to develop, the better off every one will be. With a consciousness that his knowledge will spread for the good of all, the Soviet scientist adopts a strong feeling of social responsibility, a frankly political outlook and a tendency more and more to collective living, working and playing in a country where, to quote the late Academician Karpinsky, "science is given a place of honor."

RECEDING HORIZONS

By Professor HEBER D. CURTIS

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In his well-known poem "Ulysses" Tennyson makes that self-analytic Grecian wanderer say:

I am a part of all that I have met;
Yet all experience is an arch wherethro'
Gleams that untravell'd world, whose margin fades
For ever and for ever when I move.
. . . . . .
And this gray spirit yearning in desire
To follow knowledge like a sinking star
Beyond the utmost bound of human thought.

The thought thus beautifully expressed was by no means new in Tennyson's day. Philosophers, thinkers, religious believers, even the man in the street of ancient or more modern times, have all given an awed adherence to the thesis that the ultimate in knowledge is unattainable—that, however so many the new data of the universe that may be found by man, there always will be revealed other facts beyond, and a new, wonderful and apparently mysterious and unreachable horizon will be glimpsed in the distance to take the place of the horizon that has just been attained.

It was an Englishman who expressed this thought in a somewhat more concrete form when he said, "Any good theory brings in more problems than it removes." That our body of observational knowledge can never reach an end in some final and ultimate horizon is a truism that seems generally admitted. Though the illustration may seem somewhat far-fetched, the increases in data secured by man through the ages may be somewhat fancifully compared to that mathematical curve known as the rectangular hyperbola, one of whose characteristics is that it will never touch the two straight lines to which it is referred, though it will asymptotically come infinitely close to such a contact after the lapse of unlimited time.

It is a rather comfortable and satisfying curve of progress, to minds that are pleased with such speculations. For if we consider the conditions of its approach to one of its rectangular axes, we may argue that additions to knowledge will gradually become relatively smaller and smaller as we gradually approach to, but never reach, the line that represents complete and final knowledge. But the curve may equally well be reversed for the benefit of those who wish to dream their dreams in accordance with the assumption that man's progress was at first almost infinitely slow; then we may postulate that future additions, future discoveries and future intellectual progress will become almost infinite in the magnitude of the individual Brobdingnagian strides we shall be making, even though our progress to the line representing the absolute will be as infinite in duration as it was from the former view-point.

Many will feel that the last-mentioned point of observation for such holiday dreams appears to be more accordant with our own evaluation of the advances recently made in pure and applied science. But the view-point depends entirely upon whether we appraise the utilization of fire and the invention of the first bow and arrow as relatively more or less important in man's upward climb than is radio and gasoline. It is perhaps not generally recognized that such beliefs in the limitations set upon our knowledge of the eternal verities involve one or both of two equally interesting assumptions and that astronomy is rapidly furnishing us with certain data that may some day make it possible for man to choose somewhat more certainly between these assumptions than is at present possible.

The first of these assumptions presupposes a body of facts in the universe that

we may characterize as essentially unknowable; transcendent in the usual sense of that word, though in no way transcendental in the Kantian nomenclature. This science is assumed to be unknowable as such, not because we may never have the instruments and the opportunity to study it, but intrinsically and because of the natural limitations of the human mind.

The second assumption places no final limit on man's mind or reasoning powers. It maintains that there is nothing accessible in the universe that we shall not eventually understand, granted only that is perceptual to our senses and to our adjuvant instruments of measurement; though our mentalities may be imperfect to-day, this assumption postulates they will eventually be adequate for any problem which the picture or model of the universe may present. There will then ultimately be no physical fact that is transcendent, mysterious or unknowable merely because of any supposed limitations of our intellects. But, as on the first assumption, our knowledge can only asymptotically approach the absolute, and never reach it, merely because the universe itself possesses the attributes of infinity—perhaps even *im kleinen*, and more certainly in the large, in so far as considerations of mass, extent and duration are involved. To whichever of these two assumptions we may adhere for the present as a working basis, it will be evident that we shall eventually come out of the same exit door for either.

Vast aggregations of physical and purely astronomical data may be assembled and so treated as to support either one of the two basal assumptions just outlined. For example, the phenomena of light, electricity, matter, gravitation, the molecule and the atom, the neutron, electron and positron, exhibit fields where even to-day we have a vast power of control and a rigid codification of processes, though our factual knowledge of the actual entities involved remains almost precisely zero. This condition may be taken as a support for the first assumption mentioned. Many thinkers have, for example, seriously suggested that the basal and ultimate nature of matter and radiation is something that we may have to admit is intrinsically unknowable. We recall here how Eddington has somewhat whimsically characterized the atom —"Something unknown is doing we don't know what."

We shall have to admit at this point that such an assumption of an unknowable sub-stratum may be only a short-sighted and rather naïve escape from our difficulties, open to many objections. The opponent may say with good reason that the entire history of scientific thought is one where the formerly mysterious fact has been made understandable. Is not such an assumption, such an objector will say, really a result of the same naïve reasoning as that employed by primitive man, who placed a much larger body of phenomena in the reign of the unknowable—explaining lightning, thunder, day and night, the sun, moon and stars as under the control of unknowable spirits, of good and evil genii? Primitive man made such assumptions and was entirely logical in so doing, according to his lights. He was really as scientifically minded as Eddington when he summarily dismisses the atom as beyond the pale, or as de Sitter was when he accepted a mysteriously expanding universe. For whatever objections we may voice as to the validity of the simple explanations advanced by the savage, we are to-day basally not very much more logical and scientific than he, since science consists only in observing things and then formulating the simplest possible theory to explain these things. Both Poincaré and Jeffreys have maintained with some reason that the theory that has the best *a priori* probability of being true is the theory that is simplest.

Perhaps the very simplicity and naïvete of this first assumption may prove

to be its eventual undoing. So rapidly has recent scientific progress pushed farther away from us the horizons beyond which these seeming unknowables lie, that many prefer to put aside all speculations as to a possibly transcendent physics as non-contributory and profitless and to adopt, with good reason, a waiting policy, confident that the scientific future will take care of itself and reasonably sure of the thesis that our present horizons are apparent only, certain to vanish and be replaced by new ones as they did for that ancient seafarer, Ulysses.

It is, however, of the other horn of the dilemma that I wish to treat, namely, the thought, speculation, holiday dream or whatever the critic may prefer to term it, that our horizons are receding merely because of the fact that we have to do with a universe that is infinite in both space and time. It assumes that no datum of the universe is transcendent or intrinsically unknowable; it makes the further less warrantable assumption that man's intellect will eventually asymptotically approach to an infinite knowledge.

For this phase of the discussion we shall turn to astronomy and the modern evidence of the infinitely great, and pass over the at present equally transcendent mysteries of the infinitely small—the wonder of the atom, the mysteries of radiation, the complexity of the proteins and that strange horizon, seemingly coming closer to us at present, where we appear to pass from dead matter to the virus, enzymes, bacteria and life.

I regard it as perhaps the most significant contribution ever made to philosophical thought that the astronomical development of the past two decades has given us for serious consideration eleven separate and distinct theories of an infinite universe. One such theory, it would appear, would have been sufficiently wonderful and startling, and would have formed a suitable text for mighty volumes. Of these eleven sorts of an infinite universe, two are Newtonian, that is to say, they involve only the evidence of our senses in the ordinary connotation of that phrase and are based upon the three dimensions of classical physics. The other nine types replace two earlier types that had been shown to be erroneous; they are based upon the theory of relativity and involve transperceptual relations; there are nine of them according as we assume a certain exceedingly minute and still unknown cosmical constant to be positive, negative or zero, and according to our choice of the curvature of space as positive, negative or flat. As a matter of fact, these nine types boil down to two—a universe that is actually expanding or a universe that is oscillating, that is to say, alternately expanding and contracting.

It should be pointed out at this juncture that this very recent contribution of astronomy to philosophical thought has essential differences from the concept of infinity debated by philosophers of all time. Their assumption of infinity was academic, abstract and detached; astronomy gives us a concept that is in a sense more concrete; though admittedly unattainable and unrealizable as a concept, it at least marshals some very interesting evidence and weighty mathematical analysis in its support.

One further repetition of this caution seems advisable; astronomy can certainly advance no claim to a proof or disproof of infinity in the abstract; it realizes, fully as well as philosophy, that the full knowledge of any infinite concept is beyond the finite brain of man. But astronomy may, with propriety, assert that it has, perhaps for the first time in the history of human thought, adduced certain lines of observational evidence that make some postulation of a spatial infinity at least more probable to the physical scientist.

The objection may be raised at this point that the astronomer has no right to take part in speculations whose basal character has been recognized to partake

of the insoluble in the theory of knowledge. The astronomer, says the philosopher, has neither the obligation nor the proper qualifications to make his speculations in such abstruse fields worth while, from the philosopher's standpoint. But the astronomer has become somewhat restive and refuses to be bound longer by such restrictions and prohibitions. He has defined a philosopher, somewhat ungraciously, as an individual who claims for his own and arrogates to himself all the really interesting parts of all other sciences. Though willing to admit the all-embracing character of the field of philosophy, the astronomer is to-day demanding the right to do a moderate amount of speculation of his own, even though, philosophically speaking, he may may be as a bull in a china shop. Furthermore, the physicist and the astronomer are to-day the ones who seem to be furnishing not only the puzzles, but the lion's share of the clues that may eventually clear up the puzzles in part, and the astronomer, in particular, now feels that he has earned the right to quote to the philosopher in his own defence that ancient prohibition, "Thou shalt not muzzle the ox that treadeth out the corn."

In presenting some of this evidence, I shall try to refrain from confusing the issue by citing too much of the incomprehensible numerical data of modern astronomy, though a little of this must be given here and there. For, not even if we took the wildest financial dreams of present-day politicians and translated these into Portuguese milreis or Chinese cash could we hope to equal or be able to understand our astronomical distances.

The evidence from which proceed our eleven modern theories of an infinite universe is rather simple in its outlines and in its essential characteristics. Put very briefly, our own sun is only one of several billion suns that are assembled in a great reading-glass shaped space, and this vast congeries of stars we call a Milky Way or a galaxy. Scattered throughout all the accessible space exterior to this Milky Way of ours, at distances apart that average a million light-years or more, are several hundred million other Milky Ways, each one made up of billions of suns, as is our own. These brother Milky Ways range in apparent size from large and wonderful spiral structures that are the most beautiful things in the heavens, down through successively smaller sizes, due to increasing distance from us, till finally we see them as mere flecks on the photographic plate in the most powerful telescopes that we possess. These minute specks, so small and uninteresting, nevertheless possess a great fascination for the thinking mind, for each of them possesses its billion suns, like our own galaxy, or the larger spirals relatively near to us. Actually of the same order of size as our own Milky Way, they look so small merely because they are so far away. I have, and I feel conservatively, estimated their probable distance as a billion light-years, where each light-year equals six trillion miles, or a total distance in miles that requires twenty-two figures for its expression. A Milky Way in a flyspeck!

A very considerable number of abstruse papers have been published, devoted to the manner of arrangement in space that obtains for these millions of brother Milky Ways. These studies are complicated by many factors into which I can not here go in detail—assumptions as to the possible absorption of light in space, a shifting of the total light to the red through either velocity or great distance, etc. Suffice it to say, by way of summation, that the consensus of present-day opinion maintains that these external galaxies are fairly uniformly distributed in exterior space. That is to say, their distribution possesses the factor of continuity, in the philosophical sense; as we reach farther and farther from our own part of space we do not find that the number of galaxies in a given volume is becoming smaller and that the

effective density of space is becoming less. We confidently expect the new 200-inch telescope to show us merely eight times as much of the same distribution of the same sort of things in space. It is equally remarkable that we get no strange, new and aberrant forms of Milky Ways as we go outward; the continuity in the factor of structural form and the essential simplicity of the external universe are salient facts at which I never cease to marvel.

There is, then, a remarkable uniformity in the distribution factor, as well as in the forms assumed, and space appears to be populated with Milky Ways with a density that is uniform to the greatest distances to which our telescopes reach. We have no present cause for suspecting a change in this function of density; while we can not prove, of course, that space goes on indefinitely with this same distribution, our present evidence makes such an assumption not unreasonable. To repeat, observational evidence, which is all we have as a present guide, shows nothing against an assumption of an infinite universe, and a certain amount of indirect evidence in favor of it.

Such considerations as these, though much less certainly established in 1921 than they are to-day, prompted the great Swedish astronomer Charlier to publish at that date an epoch-making paper entitled "How an Infinite World Can Be Built Up." He used no transcendent four-dimensional space for his basis, but only the three dimensions of our experience and Newtonian physics. He showed that if things outside are arranged in systems, that is, suns arranged in Milky Ways, Milky Ways in clusters, clusters of galaxies in super-galaxies, and so on, the universe could mathematically go on forever, world without end, without running into any paradoxical difficulties. And the strange and interesting thing is that this universe of Charlier's, which I regard as perhaps the most probable of the eleven infinite sorts now available, seems to parallel the observed external universe with astonishing fidelity; things "outside" do seem to be arranged in this way.

But another interesting and still somewhat mysterious factor began to enter into the field of analysis at about the time of the publication of Charlier's memoir. Without going too much into minutiae of detail, the researches upon these external galaxies made during the past twenty years have brought to light an astonishing and overwhelming fact, not yet explained in a manner to win universal acceptance. Each and every brother Milky Way, with exceptions too few to note, seems to be receding from our part of space. The speeds of apparent recession are very high; the great majority are more than four thousand times the velocity of a rifle bullet and in one case at least amount to 26,000 miles per second, or nearly one seventh the velocity of light. And recall that these velocities, once more, are not at random, with some approaching and some receding, but all are receding from us, or at least seeming to recede. Note in addition that the farther away a brother galaxy may be from us, as shown by its apparent size, the faster it is receding from us. The relation, so far as our observations go, is then a linear one, varying directly with the distance or, what is the same thing, with the time of light travel. For every million years the light-ray has been on its way toward us, that is, for every six quintillion miles of distance (6 followed by eighteen ciphers), we find that there is an increase of about 100 miles per second in the apparent speed of recession. A small library of intensely abstruse treatises has been written in the attempt to fit this astonishing and apparently universal characteristic of other Milky Ways into the coherent scheme of things. How shall we explain it, asks the astronomer?

I have mentioned the existing choice presented in several branches of science between theories based on the perceptual

on the one hand, and on the transcendent on the other. No more interesting example of this dilemma as an illustration of a present and pressing need in our physical sciences could have, so to speak, been made to order than the history of the attempts to explain this recession of other Milky Ways. Shall we then attempt to explain these peculiarities of our external universe as in every way conforming to what we sometimes loosely term the evidence of experience, that is to say, as given by our senses in the usual connotation of that term? Or shall we, on the other hand, call in to our aid the transcendent, the mysterious, the trans-perceptual?

It is either fortunate or unfortunate, depending upon the individual point of view, that a body of transcendent physical theory was already at hand and available a decade before the peculiar fact of the recession of other Milky Ways was firmly established by observation. I am fully aware that any ardent believers in the theory of relativity who may read these words will object strenuously to my characterization of the Einstein theory as in any way transcendent, yet I feel that this is not an overstatement. The so-called Newtonian universe of Charlier and what we now term classical physics was definitely based upon the three dimensions of experience with that still somewhat mysterious phenomenon known as time as a separate entity. The mathematics of relativity is essentially four-dimensional, and time and space do not in this theory possess an independent existence, but are united in a single space-time relation. The relativistic fundamentalist regards this union of time and space as a very beautiful contribution to logical thought, and does not hesitate to evaluate it as a contribution far superior to any made by Newton.

Those who to-day do not accept the theory of relativity as inevitable are very definitely in the minority—that must be admitted. But there is still a fairly weighty minority of scientists who are unwilling to admit that the concept of contiguity in a space dimension is inseparably and indissolubly bound up, in the fundamental nature of things, with the concept of consecutiveness in a time dimension, however these two concepts may be fused in the recorded observations. We listen to the puzzling dissertations on the peculiarities of imaginary clocks on moving systems, with intercommunicating signals sent with the fundamental velocity of light, and while admitting that light coming from enormous distances, brings to us living energy of the remote past but in the present tense, are still unconvinced and feel that this has no vital connection with *das Ding an sich*—the actual structure of the external universe.

These words of doubt should not in any way be taken as a dictum on my part that relativity may not be true; such a statement would not only be foolish, but may well prove eventually to be false. The late G. K. Chesterton put into the mouth of Father Brown, that interesting philosophical priest of his creation, the words, "Ten false philosophies will fit the universe"; it is indeed possible that the Newtonian universe of our sense perceptions may turn out to be one of the false ten, while a trans-perceptual universe may be accepted. For it is in no way the purpose of this discussion to enter the lists for or against the theory of relativity, as such. It is rather to emphasize and draw to your attention the strange forks in the road at which astronomy to-day finds itself, and one fork leads to the Einstein theory. To repeat—we have before us a certain dilemma of choice, and never before in the history of physical theory has the choice been put before us so definitely, with one fork of the road leading to a Newtonian universe perceptual by our experience, and the other fork taking a course that leads to some type of relativity universe that may perhaps be described, so long as our brains function

in their present mold, as transcendent and trans-perceptual.

The history of the attempts to describe the universe as four-dimensional in the relativity sense and in particular to explain thereby the apparent recession from us of all other Milky Ways as a necessary consequence of the introduction of a combined time-space coordinate, has exhibited interesting changes.

By 1917 both Einstein and de Sitter had postulated closely allied forms of a four-dimensional universe; in Einstein's form the space-time element was quasi-cylindrical, in de Sitter's it was quasi-spherical; in so far as the mathematical treatment was involved. In these two earlier relativity universes the recession of other parts of the universe was apparent only; that is, it was part of the fundamental basis of things that distant objects should *seem* to be moving away from us, but no actual physical expansion was involved.

These two universes held sway till about 1929, when almost simultaneously a brilliant young American, Tolman, and a very able Belgian priest, the Abbe Lemaître, proved that the universes of Einstein and de Sitter were unstable, because of their static construction, and hence could not exist. Both Einstein and de Sitter accepted these conclusions, and there gradually arose a new body of theory which may be described, very roughly, as a kinetic relativity universe, in which the observed recessions of other galaxies are *real;* the acceptance of this modern form of the theory means, of course, that the universe is actually expanding at a high rate of speed, and the farther we move from our part of space, the greater is the rate of expansion. McRae and McVittie, a little later, maintained that such a universe must necessarily contract; inasmuch as these two investigators are Scotch, as indicated by the two first letters of each of their names, some thus found an element of humor in a subject otherwise unutterably dry. This interesting conclusion has since been withdrawn, however.

De Sitter later showed that nine types arose, depending on the initial assumptions mentioned earlier, which effectively reduced to two sorts, expanding or oscillating, nor can any available evidence decide which assumption is the more correct. No important alteration in this theory has been made during the past few years, though papers continue to appear on certain aspects of the analysis.

We find to-day among the adherents of the theory of relativity all shades of opinion as to the reality of the theory of an actually expanding universe. Some relativists accept the theory in a somewhat cautious and guarded fashion—as an interesting possibility, not yet fully proven. A smaller number, among whom we may mention that very able, definitely mystical and apparently somewhat credulous Quaker, Eddington, have championed the expansion theory with an unbounded enthusiasm. Eddington is even ready to assume that two billion years ago all the hundreds of millions of other Milky Ways that we can detect with our powerful reflectors were concentrated within the relatively small volume of a single Milky Way, or in some sort of giant primordial molecule, the germ from which all the physical creation has sprung. To the objection that two billion years is not a very long time, geologically and biologically speaking, Eddington has said that we must shorten these vital and apparently firmly established time-scales. Small wonder that one able reviewer has expressed in print his wonder whether Eddington himself really believes all such bizarre conclusions! We thus find to-day two schools of thought among the only true believers, for so they regard themselves. One school follows Eddington in taking literally the observed facts as to the recession of the external galaxies and demands the so-called short time-scale for the process, the word "short" being used in its astro-

nomical or geological sense as a quantity of the order of one or two billion years from the very start till the present. The other school accepts an expanding universe, but seeks evidence or qualifying facts that will permit the use of the long time-scale, which grants to the astronomer a time of expansion perhaps a million times longer, and probably sufficient for the life period of the component stars that form our Milky Ways, for the formation of our solar system and for the age-long processes of geology and biology. No school has as yet arisen as a champion of the theory of an oscillating universe, perhaps simply for the reason that no evidence whatever can be found that bears on such a possibility.

A Newtonian infinite universe will, of course, have no horizon other than the horizon that marks the limit of present or future telescopic power. The various possible types of relativity universe have, however, an actual horizon of a very curious sort, referred to with some frequency in papers in this field, even though it is probably little more than a mathematical figment. This relativity horizon is as unattainable in reality as the utmost bounds of a Newtonian infinite universe in that neither our telescopes nor the light-ray can ever actually reach to it. But it is a horizon at which the universe ends; within it exists all the matter, space, time and energy of the great whole, and beyond this peculiar horizon there exists neither matter nor space nor time.

So much then for the fork of the road that leads to the mystical, the transcendent, the trans-perceptual; many wish to travel by this fork. But there are not a few who still prefer to choose the other fork of the road, that leads to an infinite universe in the Newtonian sense, and to retain for the framework of the universe only the three dimensions of ordinary perception.

Those who desire to travel by this second fork are now asking themselves the question—is there some other way by which the apparent recession of the galaxies and the apparent expansion of the universe may be explained by a mechanism that is "reasonable," if we define "reasonable" in a very narrow sense as a function requiring no phenomena that are transcendent or contrary to what we assume are the three-dimensional limitations of our perceptions of space? The answer is that such an explanation has been suggested and is perhaps in sight, though as yet on no firm mathematical basis. I shall use "reasonable" and "unreasonable" in this very special and narrow sense, a use open to attack on a number of philosophical counts.

For in the very limited sense thus defined, it must be admitted that the concept of an actually expanding universe is "unreasonable." That a few hundred million Milky Ways, at an average distance apart of one million light-years, and spread with considerable uniformity throughout a spherical space whose diameter is a billion light-years or more, should possess some mysterious interconnection or repulsive power that drives them all away from an equally mysterious center at speeds that are an appreciable fraction of the velocity of light, certainly seems "unreasonable." It seems diametrically at variance with every known fact of present-day celestial mechanics. It can not, furthermore, be regarded as a simple theory, nor can we easily imagine a cause for this uniform motion outwards that is inherent in the nature of things, that springs inevitably from the arrangement of the matter in the universe itself.

Prophecies are easy to make, but almost uniformly wrong. So "unreasonable" does the theory of an expanding universe seem to me, however, that I venture on a prophecy, with a full realization of its possible ultimate incorrectness. It is my measured belief that a century from now the physicist and the astronomer will look back upon this theory of 1938 with a

somewhat tolerant smile and that he will mentally classify it along with the chemical theory of phlogiston or the pre-evolutionary tenet that fossils were created as such, *in situ*, with no previous vital activity in a living animal. This prophecy applies only to a certain result that has been adduced from the theory of relativity, not to the theory itself. For all I know, they may possibly be teaching the theory of relativity in the grammar school one hundred years from now, though I strongly doubt it.

We must then search for some alternative and apparently "reasonable" theory, if indeed such exists, in the light-ray itself. If something happens to the light-ray in its passage through quadrillions of miles of space that can shift the lines of the spectrum to the red we shall still have the measured speeds of recession that we at present observe in distant Milky Ways, but this recession will be only *apparent* and not *real*, and our universe will not be expanding. We shall be just as logical in such a course as was the relativity theory of 1920 which, as stated earlier, postulated that the expansion of the universe was apparent only. Our possible explanation, however, will require no excursion into the limbo of a fourth dimension, nor will it require a formulation of the framework of the universe in 16 equations, each with 16 terms, or 256 terms in all.

Such an explanation, which seems not "unreasonable" *a priori*, will then seek for the cause in the equations of light, and a relatively simple physical fact will take the place of a transcendent framework. It must be admitted at this point that we do not as yet have the mathematical and physical proof for such a behavior of light, but a number of theorists are being attracted to the possibility of such an explanation. It must be admitted, also, that some of these attempts, based upon the quantum theory of light, seem to lead to a cul-de-sac, so that some investigators have stated it to be impossible. It requires, to put it simply, that something must happen to the light-ray to cause the vibrations of the light to be slowed up a very little, so that the crests between the waves are farther apart. It is as though the vibrational aspect of light becomes a little tired in its passage through the tremendous reaches of space. Such an explanation would apparently leave untouched, however, the velocity of light itself in free space. The ratio by which the vibrations become slower and the light waves a little longer is exceedingly minute, it may be added. To fit the observed facts this factor of expansion needs to be only one quarter of a quintillionth, or a fraction whose numerator is unity and whose denominator contains 18 digits. Let no one object at this point that we do not know the nature of radiation, nor what the light ray is, nor whether its waves have crests. That is admitted, for science must perforce be concerned first with phenomena, and only later, if possible at all, with the basal entities that seem so far beyond our receding horizons.

I feel that such a solution of our dilemma will ultimately be found and that we may then proceed on that fork of the road that presupposes a three-dimensional universe. This article must remain as far as possible untechnical, though it touches fields on the borders of present-day analysis. It is worthy of mention, however, that Maxwell's fundamental electromagnetic equations, which are partial differential equations of the second order, contain in their derivation by that great master, a term that is the sum of three first order derivatives. Maxwell pointed out that this term would be either zero, a constant or linear with the time, and hence could not affect the wave motion proper, so he discarded this term in his solution. As a matter of fact, he apparently had to do this to get a convenient solution. But it is at least possible that the solution of our expanding

universe difficulties may lie in this discarded portion, for as this may be linear with the time, it could permit some relation that would increase with the distance traversed by light. It should be once more emphasized, however, that the proper solution permitting this has not yet been rigorously formulated.

So much, then, for the interesting dilemma that present-day astronomy offers the philosopher. Whether we shall eventually be content with a three-dimensional perceptual universe and find the cause of our difficulties removed by adopting some new analysis of the light equation based on classical physics, or whether we shall continue to follow the present trend and seek to find a solution in a universe that is four-dimensional and in a sense trans-perceptual, still rests on the knees of gods. Certainly, in either event, our horizon will continue to fade forever and forever as we move.

Nothing, in fact, is more startling than the way our horizons have receded since the beginning of this century. In 1900 we talked with great hesitation and uncertainty of distances as great as five thousand years of light travel; now we with far less uncertainty speak of distances of a billion light-years; we have caused our horizon to recede ten thousand-fold during the past three decades. The proposed 200-inch telescope will theoretically push the accessible horizon twice as far away as now observed and make it twenty thousand-fold as distant as it was a quarter of a century ago. We expect with this great instrument to do a great many things much more quickly, but the conservative astronomer, unmoved by the clamors of the press for something really interesting, knows that we shall simply reach twice as far and study a volume of space eight times as great as that now accessible, and that we shall find in this added volume just eight times more of the same sort of universe we now have.

This, of course, is not enough, though we can at present envisage no new instruments that can place our actual observational horizon farther away. But we can always go on from what we have by invoking the apparently universal principle of continuity that obtains in the world outside and beyond these receding horizons. With the tools of mathematical analysis we can extrapolate, a rather dangerous process in many lines of physical research, but one that has thus far shown no weakness when applied to the external universe. On the wings of the intellect we can fly far beyond our receding horizons and the astronomer to-day demands as his right the privilege of speculation on the existence and arrangement of an infinite universe, infinite in both space and time, with all the interesting conclusions that may follow such a speculation, surely the most daring step that mere physical observation has ever permitted us to make.

We still are uncertain whether we may have to bring in the transcendent and unknowable in such speculations, or whether our infinite universe includes only the physical facts that are knowable with our finite brains and measurable with our gross measuring instruments of science. But we are happy in the realization that our astronomical horizons are receding ones; that apparently we shall have the joy and pleasure of achievement for all time to come in pushing farther and farther from us the limits of that untraveled world whose margin fades forever and forever as we move.

SURGICAL MAGGOTS IN MODERN MEDICINE

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Introduction

Many thousands of lives were taken during the world war, but just as many thousands of lives have since been saved because of the scientific achievements which resulted from it. One of the outstanding achievements is the utilization of maggots in the treatment of the bone infection known as chronic osteomyelitis. This disease is difficult to cure, often lasting years and causing a great deal of suffering. It is caused by pus-forming bacteria, such as the streptococci and the staphylococci, which make their way into the body through abrasions of the skin or through injuries from fractures, burns, deep cuts, gunshot wounds or explosions. The disease can also develop from some other infection of the body, such as an abscess, in which instance the organisms are conveyed to the bone by the blood stream. Although the maggot treatment was at first confined to osteomyelitis, experience has shown that it is just as effective in many other forms of disease known generally as "suppurative infections." Its applicability has extended even to the field of dentistry, where successful treatment of osteomyelitis of the mandible has been reported.[1]

Historical

The observation that maggots are of aid in curing disease can be traced as far back as 1557 when Ambroise Paré, the famous French surgeon, called attention to the beneficial effects of maggots in suppurative wounds. In 1799 D. J. Larrey, the celebrated military surgeon of Napoleon's armies, observed the curative properties of live fly-maggots in the extensively infected wounds of soldiers. J. F. Zacharias, a surgeon in the Confederate Army, was perhaps the first person who intentionally employed maggots in wounds. At the beginning of the twentieth century Larkin, a Chicago surgeon, used maggots in the treatment of osteomyelitis and chronic septic infections, and reported favorable results. But in spite of the fact that beneficial effects of maggots have been noted time and time again, the late Dr. William S. Baer,[2] of the Johns Hopkins University, was the first surgeon to put this age-old remedy into use on a scientific basis and to employ it in civil surgery.

Baer's Observations and Early Research

The initial impetus for Dr. Baer's subsequent work was an observation he made while he was serving with the American Expeditionary Forces on the battlefields of France. After a battle in 1917 two soldiers with compound fractures of the femur and large flesh wounds of the abdomen and scrotum were brought into the hospital. Although these soldiers had lain on the battlefield for seven days without water or food and had been exposed to the weather and insects of that region, they had no fever and there was no evidence of septicemia. Except for their starvation and thirst, they were in remarkably good condition. This unusual circumstance, in view of the extent of their wounds, and particularly in view of the fact that the mortality of compound fractures of the femur was about 75 to 80 per cent., even when the wounded had the best medical and surgical care that

[1] N. C. Ochsenhirt and M. A. Komara, *Jour. Dent. Research*, 13: 245–246, 1933.

[2] W. S. Baer, *Jour. Bone and Joint Surg.*, 13: 438–475, 1931.

the Army and Navy could provide, attracted Dr. Baer's attention. When he removed the clothing from the wounded parts, he was surprised to find the wounds teeming with thousands of maggots, presumably those of the blowfly. And when the wounds had been irrigated with normal salt solution, he was even more surprised to find that instead of being filled with pus, which he expected as a result of the degeneration of devitalized tissue and the presence of numerous types of bacteria, the wounds were filled with a healthy pink granulation tissue; there was practically no bare bone to be seen; and the inside surface of the injured bone, as well as the surrounding parts, was entirely covered with the same pink granulation tissue which filled the wounds. Bacterial cultures showed a few staphylococci and streptococci, but not enough to cause pus formation. The maggots had accomplished their task—the wounds had healed.

What Dr. Baer saw on the battlefield made a deep impression on him. Finally, after thinking about this experience for ten years, he decided to test by experiment the possibility of putting his observations into practical use in civil surgery.

In September, 1928, four children suffering from chronic osteomyelitis were admitted to the Children's Hospital School in Baltimore. Each child had previously undergone operation three or four times and had been treated over a period of from one to five years. On these children, who had been unsuccessfully treated by the usual methods, Dr. Baer began his first work in the treatment of osteomyelitis with maggots. First all the dead tissue was thoroughly removed from the affected areas. Then maggots of the blowfly, obtained from the immediate neighborhood, were placed without sterilization into the wounds. The maggots were replaced several times. At the end of about six weeks, the wounds had healed completely—the deeper structures as well as the skin.

The experimental treatments were continued. In the early treatments, however, difficulties arose from secondary infections. In three instances gas bacilli were discovered in the wounds. Although the patients presented no clinical symptoms of gas gangrene, all treatments were discontinued and research begun to solve the problem. From the experiments conducted, Dr. Baer was able to show that maggots destroyed rather than caused gas bacilli infection. And he concluded that in order to overcome gas bacilli it would merely be necessary to increase the quantity of maggots, after first making sure that the maggots placed into the wounds were free from all gas bacilli.

Following these findings, the treatment of wounds with maggots was resumed. But it was not long before tetanus (lockjaw) bacilli were found in the wounds of some of the patients. These wounds were quickly washed out, and the patients were given injections of tetanus antitoxin. Four patients manifested no clinical symptoms; two developed severe lockjaw; one, who had been suffering from advanced tuberculosis of the ankle, lung and spine, died in spite of the administration of large doses of antitoxin; and the last patient finally recovered after a long struggle with the infection.

From this disconcerting experience, Dr. Baer realized that in civil practice it would be necessary to use sterile maggots, and that in order to have at hand a supply throughout the year, flies would have to be grown successfully in the laboratory. After extended research a successful technic was devised for growing the flies and producing sterile maggots.

Dr. Baer continued with his maggot treatment of chronic osteomyelitis until April, 1931, when he suddenly died. Fortunately, he had observed and had treated a large number of patients, and

had been able to report 95 per cent. cures in children and 85 per cent. cures in adults. So excellent were the results he obtained that it was not long before many other surgeons adopted his method of maggot therapy. A recent report[3] shows that the treatment has been given in every state in the United States as well as in Canada and a large number of foreign countries.

Species of Larvae Used

The larvae used in maggot therapy are those that live only upon decaying and necrotic tissue. Satisfactory larvae are obtained from the bronze-green blowflies, *Lucilia sericata* (Meigen) and *L. caesar* (Linn.); the blue-black bottlefly, *Phormia regina* Meigen; and the large blue bottle-flies *Calliphora erythrocephala* (Meigen), *C. vomitans* (Linn.) and *Cynomyia cadaverina* Desv. Of the flies used, *Lucilia sericata* and *L. caesar* are the most satisfactory because of the ease with which they can be handled in the laboratory. Great care must be exercised to identify correctly the species of fly to be used, for the larvae of some species of flies are unable to distinguish between dead and living tissue and will feed as voraciously upon healthy tissue as upon dead tissue. The screw-worm flies *Cochliomyia macellaria* (Fabr.) and *C. americana* C. and P. are well-known examples of this.

Life History of the Fly

There are four stages in the life history of the blowfly, namely: (1) egg, (2) larval (maggot), (3) pupal, and (4) imago (adult). It takes from 10 to 24 hours for the eggs to hatch. The larval stage consists of two periods—(a) the active feeding and growing period, generally from 4 to 7 days, during which the larvae feed voraciously and are of surgical use; and (b) the prepupal or inactive period, usually from 3 to 4 days, during which the larvae do not feed and are useless for surgical purposes. The pupal stage generally lasts from 5 to 10 days. During this time the maggot undergoes transformation and emerges as a fly. On an adequate diet, the adult fly, as a rule, begins to lay eggs within 10 days after its emergence. Under laboratory conditions the life cycle of the fly is about 25 to 30 days.

Culture of Flies

Various methods of culturing both maggots and flies have been reported in the medical literature. The following procedure is the one most frequently employed.

The flies are reared in small cloth or wire cages which are kept in incubators maintaining a temperature of about 78 to 80 degrees F. and a relative humidity of between 40 to 65 per cent. The flies are given sugar, water and meat. Meat is an essential part of the diet, for without the presence of some nitrogenous material the female flies fail to develop sexually. This, however, does not apply in the case of the male flies. One feeding of meat is all that is necessary, and meat is subsequently added only when it is desired to collect eggs.

The flies continue to lay eggs well for about 3 to 4 weeks, after which time egg production and viability of eggs decrease. When this condition occurs the flies are destroyed and replaced by new colonies.

When new colonies of flies are to be established, the meat on which the eggs have been deposited is placed into a small glass feeding dish, which is in turn placed into a larger receptacle containing about an inch of sand. The outer receptacle is then covered to prevent the escape of the maggots after the eggs hatch. When the maggots are full grown (about 16 mm in length) they stop feeding, leave their food and migrate to the sand to pupate. When migration has ceased, the feeding dish and remaining food are removed,

[3] W. Robinson, *Am. Jour. Surg.*, 29: 67–71, 1935.

and the maggots are left undisturbed in the sand until pupation has occurred. When the flies emerge they are transferred to the brood cages and provided with food.

Culture of Sterile Maggots

The danger of introducing pathogenic organisms into the wounds with nonsterile maggots and the importance of employing sterile larvae in the practice of maggot therapy have already been brought to view under the discussion of Baer's early research. Aseptic bacteriologic technic is of the utmost importance throughout the entire process.

Before sterilization is begun the eggs, which are almost invariably laid in masses, are carefully separated so that the entire surface of each one is covered by the disinfectant. Separation is accomplished mechanically by agitating the egg masses in water or by carefully spreading them apart with a spatula. When separation is complete, the eggs are sterilized, generally in a formalin or mercuric chloride solution. After that, they are washed with sterile water and transferred to sterile food in glass containers. Here the eggs hatch into maggots, and the maggots feed and grow until they are ready for use. At the end of about three days' growth, the maggots reach a length of about 6 mm, the size desirable for surgical purposes. Before being employed in wounds, maggot cultures are tested for sterility, and those which show contamination are discarded.

Method of Treating Infections with Maggots

Before maggot therapy is instituted, the infected area is opened wide and thoroughly cleansed of all macroscopic debris and necrotic tissue. Minor infections need not be treated surgically. After the cleansing operation is completed, the wound is carefully packed with sterile vaseline gauze, which is left undisturbed for about 24 hours, or until all the bleeding has stopped, because maggots are repelled by blood and do not function well in its presence. When the packing is removed, from 200 to 1,000 maggots, depending upon the extent and condition of the infection, are placed into the wound. The wound is then covered with a wire screen, or with gauze, which is tightly fastened down to prevent the escape of the maggots.

The maggots feed upon the necrotic and purulent matter within the wound. In three to five days they reach their full growth and stop feeding. At this stage, no longer being useful, they are washed out of the wound with sterile salt solution. The patient is then allowed to rest for about 24 hours. At the end of that time, a new lot of maggots is introduced.

The length of time that maggots feed in the wound depends upon their size when they are implanted. The feeding period at the beginning of the treatment is longer than that toward the end of the treatment because maggots do not feed upon viable tissue and as the wound is cleaned up less food is available for them. When all the necrotic and decaying tissue has been devoured, the maggots die from insufficient nourishment.

The number of maggot implantations necessary depends largely upon the individual patient and the character of his wounds. The implantations range from 1 to 25, and sometimes more. For example, in children the healing period for chronic osteomyelitis of the long bones is about six weeks. In adults this period is at least a third longer.

Factors Effecting Cure in the Treatment of Infections

It has been found that maggots aid in the cure of infections in many ways. Among the important beneficial actions are the following:

(1) Since maggots feed upon decaying

and necrotic tissue, and so remove it from the wound, conditions for bacterial development are unfavorable. In their feeding, maggots also ingest numerous bacteria which are destroyed as they pass along the alimentary tracts of the maggots.

(2) During the course of the treatment, the wound secretes a thin, serous discharge which carries out with it great numbers of bacteria, thereby decreasing the number within the wound.

(3) The proteolytic end-products, which would otherwise be absorbed by the patient's system or remain in the wound and furnish a favorable medium for the bacteria, as well as the destructive bacterial exotoxin are ingested by the maggots and are rendered inert.

(4) The massage effect produced by the vermicular motion of the maggots on the granulating areas has been found to be a beneficial action.

(5) During the period of treatment there is a change from an acid condition, characteristic of infected wounds, to an alkaline condition. This change is effected by the production of ammonia as a result of liquefaction of necrotic tissue by the maggots and of the exudation of calcium carbonate through the body walls of the maggots. The alkaline condition thus produced is above the optimum reaction for the growth of many of the organisms associated with suppurative infections, and hence results in their destruction.

(6) It has been shown that allantoin ($C_4H_6N_4O_3$) and urea ($NH_2 \cdot CO \cdot NH_2$), found in the urinary secretions of maggots, have excellent therapeutic qualities.

Diseased Conditions Treated with Maggot Therapy

Table 1, prepared by Robinson,[4] is a summary of the various diseased conditions which have been treated with maggots. Robinson points out that they are all of a purulent nature, and he states that maggots have generally not been found satisfactory for use in tuberculous bone lesions unless they were complicated by osteomyelitis. He further states that maggots have been used with some success for the removal of superficial, sloughing, cancerous areas, but not before necrosis occurs.

TABLE 1

Suppurative Infections Treated with Maggots

Abscesses,	chronic
	tubercular
Burns, with infected necrotic areas	
Carbuncles	
Cellulitis	
Decubitus, sloughing	
Empyema, chronic	
Felons	
Gangrene,	arteriosclerotic
	diabetic
	gas
Grafts (infected),	bone
	muscle
	skin
Mastoiditis	
Osteomyelitis,	acute
	chronic—all bones
	tuberculous
Periostitis	
Ulcers,	chronic
	syphilitic
	varicose
Wounds,	infected
	sloughing malignant

Discussion of Objections to Maggot Therapy

The most frequent objections to maggot therapy have been that the method is time-consuming, expensive and troublesome. Some objections have been that pain and discomfort to patients were often very great, and that the nervous tension experienced by patients with vivid imaginations at the thought of allowing maggots to feed upon them far exceeded the good that the treatment may have done. A few objections have

[4] *Ibid.*, p. 68.

been raised as to the efficacy of the treatment itself.

Although some of these objections may have been justified during the earlier period of maggot therapy, they are now no longer important because of the many improvements in the process of culturing sterile maggots and in the application of the treatment.

To reduce the cost of production of maggots, doctors living in the same vicinity rear maggots on a club plan. The author, in a recent study of an economical method of culturing surgical maggots,[5] has found that maggots can be cultured at a very nominal cost and without elaborate apparatus.

Pain[6] and discomfort, although never of a serious nature, have been greatly mitigated by the use of sedatives and by newer methods of applying the treatment. Since the psychological attitude of the patient is an important factor in the treatment, the fullest cooperation of the patient must be enlisted in order to derive the best results. Some surgeons believe that the method can be used more advantageously in patients of a low psychological type who are more or less indifferent to the presence of maggots. Other surgeons have expressed the belief that patients of higher intelligence and morale are the most desirable for treatment. Still other surgeons think that the method can be carried out most successfully when the patients understand and appreciate what is being done for them.

Concerning the efficacy of the treatment itself, its wide acceptance is sufficient proof of its merits.

[5] M. S. Tarshis, *Jour. Lab. and Clin. Med.*, 22: 1055–1061, 1937.

[6] Pain is usually the result of the exposure of nerves by maggot feeding.

Summary

One of the first observations that maggots were of aid in curing disease was made in 1557. However, it was not until the late Dr. Baer, in 1931, put maggot therapy on a scientific basis that the method became widely used in the treatment of suppurative infections. It is now considered by an increasing number of surgeons to be an inexpensive, simple and efficacious treatment.

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PRIMITIVE FISH-HOOKS

By ELKAN J. MORRIS
NEW YORK, N. Y.

MAN in the first stage of his existence took much of his food from the water. If on certain stretches of land intersected by rivers, dotted by lakes or bordering on the seas, shell-fish, cetaceans and fish were found to the exclusion of land animals, primitive man might have been forced to depend upon the art of fishing.

After brute instinct, which is imitativeness, came adaptability. The rapid strides of civilization, considered in their material sense, are due solely to the use of such implements as are specially adapted for a particular kind of work. With primitive man this could not have been the case. Tools, whether they were axes, hammers or arrows, must have served the river-drift and cave-men for more than a single purpose. People with few tools adapt these to a variety of ends. The Kafir with his assegai fights his battles, kills his cattle, carves his utensils and shaves himself. It is only as man advanced that he devised special tools for different purposes.

According to our present acquaintance with primitive habits, if man existed in the later Miocene, and used a lance or spear for the killing of land animals, he probably employed the same weapons for the destruction of the creature—possibly of gigantic form—inhabiting the seas, lakes and rivers. The presence of harpoons made of bone, found in so many localities, belonging to a later period may not in all cases point to the existence of animals but the presence of large fish.

Following closely the advance of man, when his implements for fishing are particularly considered, we are inclined to believe he first used the spear for taking fish; next the hook and line; and later the net. It is possible that for a time he also used the bow and arrow.

Interesting as the history of primitive history is, we, however, occupy ourselves with the forms of the primitive fish-hook. The earliest form probably was a small piece of polished stone. The illustration (Fig. 1, a) was copied from one at the American Museum of Natural History. It was found in the valley of the Somme, France, in a peat bed twenty-two feet below the surface. The age of this peat bed has been variously estimated; later authorities, however, place it about 7000 B.C.

Wonderful changes have occurred

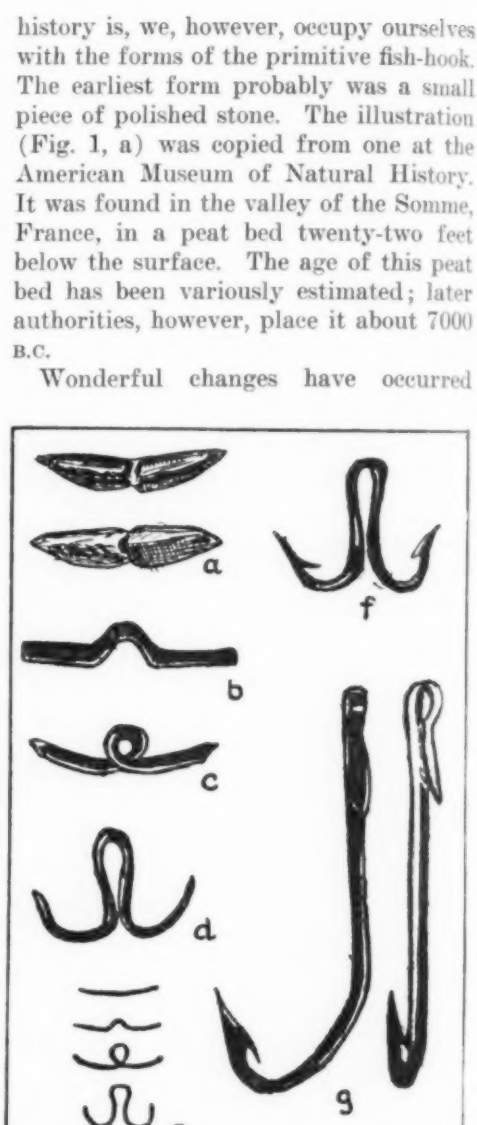

FIG. 1. *a*. STONE FISH-GORGE, FROM THE VALLEY OF THE SOMME. *b*. BRICOLE, FROM THE LAKE OF NEUFCHATEL. *c*. BRICOLE, OF A LATER PERIOD. *d*. DOUBLE HOOK, FROM THE LAKE OF NEUFCHATEL. *e*. PREHISTORIC FORMS. *f*. DOUBLE HOOK, BARBED, FROM SWISS LAKES. *g*. BRONZE FISH-HOOKS.

since this bit of polished stone was lost in what once was a lake. Examining this piece of worked stone, we find it fairly well polished, though the action of countless years has weathered its smooth surface. In the center a groove has been cut and the ends rise slightly from the middle. It must have been tied to a line and covered with bait; the fish swallowed it and the gorge coming crosswise with the gullet was captured.

The evolution of any present form of implement from an older one is often more cleverly specious than logically conclusive; nevertheless, I believe that in this case, starting with the crude fish gorge, I can show the steps that ultimately end with the perfected hook of to-day.

In the Swiss lakes are found the remains of the Lacustrine dwellers. Among the many implements discovered are fish gorges of bronze wire. When these forms are studied we notice they are copies of the stone gorges of the Neolithic period. It is fairly well known now that the early bronze worker invariably followed the stone patterns. The Lacustrine gorges have been named bricole. A bronze bricole (Fig. 1, b) found in the lake of Neufchatel is made of bronze wire and is bent in the simplest way, with an open curve allowing the line to be fastened to it. The ends of the gorge are very slightly bent, but were probably sharpened when first made.

A bricole which varies from the rather straight ones, found in the Lake of Neufchatel, belongs to a later period (Fig. 1, c). It is possible to imagine that the lake dweller, according to his pleasure, made one or the other of these two forms of fishing implements. As the double hook (Fig. 1, d) required more bronze, and bronze at first was very precious, he might not have had material enough in the early period to make it. This device is, however, a clever one, for a fisherman of to-day who had lost his hook might imitate it with a bit of wire.

When we compare the four forms, showing only the outlines, (Fig. 1, e) evolution of the fishhook can be better appreciated. Returning to the stone gorge, the work of the Neolithic period, it is evident that the man of that time followed the shape handed down to him by his ancestors; and as this fashioned stone from the valley of the Somme is of a most remote period, how much older must have been the Paleolithic fish-gorge of rough stone. It might have been with a splinter of flint attached to some tendril, in lieu of a line, that the first fish was taken.

In tracing the history of the fish-hook, it should be borne in mind that an overlapping of periods must have taken place. By this is meant that at one and the same time an individual employed tools or weapons of various periods. To-day, the western hunter lights his fire with a match. This splinter of wood tipped with phosphorus, the chlorates, sulfur or paraffin, represents the progress made in chemistry from the time of the alchemists. But this trapper is sure to have stowed away in his pouch, ready for an emergency, his flint and steel. The Eskimo, the Alaskan, shoots his seal with an American repeating rifle and, in lieu of a knife, flays the creature with a flint splinter. The net of the Norseman to-day is sunk with stones or buoyed with wood —certainly the same devices as were used by the earliest Scandinavian—while the net so far as the making of the thread goes is made by the most modern of mechanical appliances. Survival of forms require some consideration apart from that of material, the first having much the stronger reason for persistence. It is then very curious to note that fish-hooks not made of iron and steel, but of bronze or alloys of copper, are still in use on the coast of Finland.

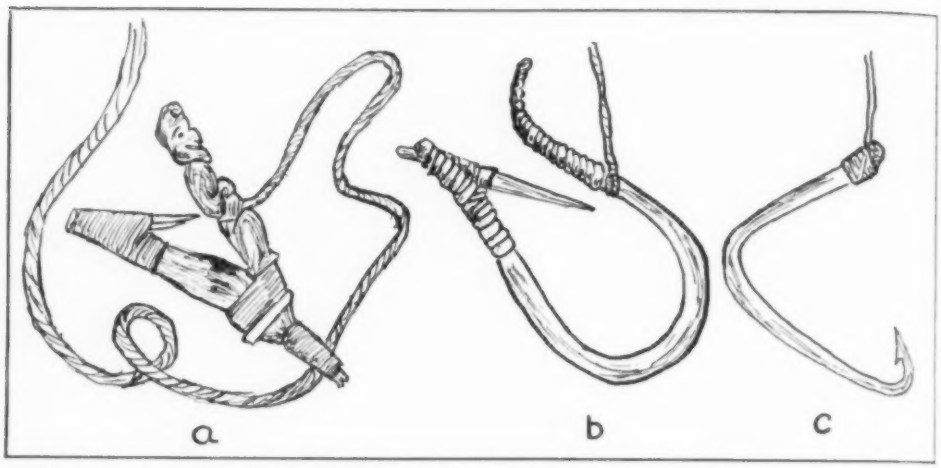

FIG. 2. *a*. ALASKAN FISH-HOOK. *b*. ALASKAN HALIBUT-HOOK. *c*. RUSSIAN FISH-HOOK.

The origin of the double hook having been satisfactorily explained, to make the barb on it was readily suggested to the primitive man, as he had used the same device on fish-spears and harpoons.

This double-barbed hook from the Swiss lakes is quite common (Fig. 1, f). Then, from the double to the single hook the transition was rapid. Single bronze hooks of the Lacustrine period sometimes have no barbs. Such differences as exist are due to the methods of attaching the line.

Hooks made of stone are exceedingly rare, and though it is barely possible that they might have been used for fish, I think that this is not conclusively shown. This, however, must be borne in mind; in catching fish, primitive man could have had no inkling of the present curved form of the fish-hook, which, with its barb, secures the fish by penetration. A large proportion of sea-fish and many river fish swallow the hook, and are caught, not by the hook entering the jaws, but because it is fastened in their stomachs. In the fisherman's language of to-day, a fish so captured is "poke-hooked"; and accordingly, when the representative of the Neolithic period fished in that lake in the valley of the Somme, all the fish he took must have been poke-hooked. A bone hook, excellent in form, has been found near the remains of a huge species of pike (Esox). Hooks made of the tusks of the wild boar have also been discovered with the Lacustrine remains.

In commenting upon the large size of the bone hook, its proximity to the remains of a large fish was noticed. When the endless varieties of hooks belonging to savage races are subjects of discussion, the kinds of fish they serve to catch should always be cited. In the examples of hooks which illustrate works of travel, a good many errors arise from the simple fact that the writers are not fishermen. Although the outline of the hook be accurately given, the method of securing it to the line is often incorrectly drawn.

In Fig. 2, b, an Alaskan halibut hook is represented. The form is a common one, and is used by all the savage races of the Pacific; but the main interest lies in the method of tying the line to this hook. Since the fish to be caught was the halibut, the form was the best adapted to the taking of this large flatfish; but had the line been attached in any other way then exactly as represented, this big fish could hardly be caught with such a hook.

In the drawing, the halibut-hook hangs but slightly inclining toward sea-bottom,

the weight of the bait having the tendency to lower it. In this position it can readily be taken by the fish; but should it be suspended in a different way, it must be seen immediately how difficult it would be for the fish to swallow it. In this Alaskan hook must be recognized the first idea of what we call to-day the center-draught hook. A drawing is also given of a steel hook of peculiar form coming from northern Russia (Fig. 2, c). The resemblance between the Alaskan and this Russian hook is at first apparently slight, but they both are constructed on the same principle. When this Russian hook is seized by the fish and force is applied to the line by the fisherman, the point of the barb and the line are almost in one and the same direction. Almost the same may be said of the Alaskan hook.

A study of these hooks—the Alaskan and Russian—show remarkable similarity to the modern, tempered steel, barbed hooks of the world to-day.

SPEEDING UP OUR READING

By Dr. WILLIAM BURNETT BENTON
VICE-PRESIDENT OF THE UNIVERSITY OF CHICAGO

We Americans pride ourselves on being a nation of readers. But despite our high degree of literacy, few of us actually *know how to read!* It doesn't matter much what our intelligence quotient is: most of us read no better than a child should in the eighth grade. More than half of all school failures are traced to bad reading habits; even scientists and scholars often read no more efficiently than day laborers without education. To put it quite bluntly, we are a race of "reading cripples."

Teachers and psychologists since the turn of the century have been trying to devise new and more effective methods of reading. Now, after 20 years of experiment and research, Professor Guy T. Buswell, of the University of Chicago, has perfected two machines by which our faulty reading habits may be diagnosed and cured.

A few weeks ago I visited Dr. Buswell's laboratory. He put me on a stool in front of a big rambling apparatus called the "eye-movement camera" that resembles the testing machines you see in the oculist's office. My head was fitted snugly into place on a chin rest. About a foot in front of me was a printed card. The professor told me to read it aloud. As I began reading, I heard the whir of a movie camera. A couple of inches from my eyes, and at one side, were two small mirrors, with a beam of light trained on each. The mirrors reflected the movement of my eyeballs into a long tube resembling a stovepipe. At the far end of the tube was the camera, making a movie record of my eyes as they worked.

When I finished reading the card, Dr. Buswell took the film from the camera. After an assistant developed and printed it, the scientist showed me the result: a series of short jagged lines, each punctuated by irregular jerks and jumps. "That," he said, "is the way you read. Each short line represents a line of type. Each jerk shows where your eyes jumped from one phrase to another."

I learned that as we read each eyeball is moved in its socket by six muscles so coordinated in their nerve connections that they move the eyes together in a beautiful example of team work. In reading, both eyes sweep across a line of print, not smoothly as you might think, but jerkily, in a series of kangaroo jumps, "fixating" successive points along the line. We ought to cover an ordinary line of type in three jumps. Most of us take six or eight. Some persons are able

to down a line in a couple of glances; but poor readers stumble along one word at a time, going backwards and forwards and making a dozen or more eye-swings to the line. Incidentally, we are blind while our eyes are moving; they have to *stop* to see. For maximum reading speed, these stops should be about one sixth of a second; actually many of us pause for a second or more; these overlong pauses and needless backswings of the eye retary our reading speed anywhere from 50 to 90 per cent.

I asked Dr. Buswell why most of us read so wretchedly. He explained that we had been taught wrong. Almost every man and woman over 35 learned to read in school by the oral method. Our teachers had us read orally, in order to teach us how to pronounce. Since we pronounced only one word at a time, we learden to *see* only one word at a time. As a result, most of us read no more than half as fast as we should—and with twice as much muscular work for our eyes.

There you have Dr. Buswell's diagnosis of our bad reading habits. But he is not satisfied merely with diagnosing them; he has devised a second machine to remedy them. This machine, a much less complex affair than the eye-movement camera, consists of a regulation home film projector and a small screen. With its help Dr. Buswell is ready to expose his "patient" to the cure.

The projector flashes a story on a screen. not a word at a time, not a line at a time, *but a phrase at a time.* Each phrase is about a third of a line. The "patient" practices how to absorb the phrase at a glance—one glance only. When he has mastered this, he is reading a line of type in three eye jumps—only half as many as before. Not only has he become accustomed to phrase-reading, but he is denied the opportunity to glance back.

The reading film projector can be operated at any speed. For the first lesson, Dr. Buswell flashes phrases at about the patient's customary reading speed, say 200 words a minute for half an hour. The next day the speed goes up to 225 or even 250. After 20 or 30 lessons a story is being run off at 650 words a minute for those who make the most progress.

Then another movie is taken of the "cripple's" eyes on the eye-movement camera. The difference in the two films —the "before" and the "after"—is often amazing: the latter test usually shows less than half as many jagged lines. The patient is reading twice as fast, and with less eye-strain! Dr. Buswell finds that some older people (many of his volunteer "guinea pigs" are over 60) can step up their reading speed almost as easily as the young. Exceptional cases have improved 100 per cent. in 20 lessons. A group of adults recently increased their average speed by 32 per cent. in 15 lessons. The normal adult, says Dr. Buswell, can easily learn how to read 500 words a minute and understand fully what he's reading. To-day, on an average, we read only about 300.

Do you ever wonder why your eyes tire easily? Do you think it's because you've read too much? More likely it's because you've wasted your eye-power. Listen to Dr. Buswell:

"Eyes were made for the distant view —for looking at sheep on far-off hills. When we focus them on something close, like a newspaper of a book, we make their muscles tense. And don't be fooled. Those eye jumps are hard, muscular work. Figure them up and you'll find that your eyes make 240 jumps to cover a single page of a book. Try wriggling your finger 240 times, and you'll understand how often your eye muscles get a work-out on every page."

Some day, reading projectors like Dr. Buswell's may be standard equipment in schools, libraries and adult education centers. But for those who can't wait

until then, who want to start their eye-improving at home right now, the professor has a few pointers:

(1) When you read, don't "vocalize," that is, don't say the words to yourself. Vocalizing is to reading what the hunt-and-peck system is to typing.

(2) Try always to recognize whole phrases at a glance, instead of single words. Not all people read phrases in the same word-combinations, so you'll probably develop your own groupings. Rhythmic reading is *good* reading. A metronome, or even beating time with the hand, helps at first in acquiring smooth, even eye jumps.

(3) Push forward. Force yourself to read at a pace a little faster than is comfortable. "You're never learning when you're comfortable," says Dr. Buswell. At first you may find yourself backtracking oftener, but soon you will become accustomed to the new speed.

(4) Approach your reading with an attitude of genuine concentration. The more purposeful your reading, the more rapid it will be.

Mere improvement in one's technique of reading is no guarantee that a person will have a richer, more meaningful reading experience. But experiments by Dearborn of Harvard and Dodge of Yale have shown that reading becomes more pleasurable and profitable when the optical difficulties accompanying it are reduced to a minimum. If we don't know how to use our eyes, we learn painfully and only at a snail's pace. Speeding up our reading means speeding up education—not only in school, but in later life. Of course this doesn't mean that we should "race through" our reading; pausing to reflect on what we've read is one of the most valuable parts of the educational process. But, as any one can see, that's quite another matter from reading laboriously and inefficiently, a single word at a time. Until large sections of the adult population learn to read more rapidly and skilfully they will be incapable of that independence of thought which comes only from a wide and intimate knowledge of the printed word.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

ELECTRICAL GENERATION AND X-RAYS

Faraday's discovery of electromagnetic induction was the most important event of the nineteenth century, declares Dr. Arthur H. Compton, University of Chicago Nobelist in physics.

Why? "Empires would fall apart, society would become disorganized, if the electrical machines based on Faraday's discovery were put out of commission."

The discovery of x-rays by Roentgen in 1895 is perhaps the greatest event within the lifetime of persons now living. What could be of more purely academic interest than extending the spectrum of electromagnetic radiation to a thousandfold shorter wave-length?

Dr. Compton compares the consequences of Roentgen's achievement with the dramatic events of the world war.

First consider death, he says.

Such data are hard to find. The war lords do not want them advertised. In the world war there were about 8½ million soldiers killed in all the armies, one fourth of the able-bodied men now living in the United States and Canada—a tremendous slaughter.

Yet of the 450 million people then living in the countries at war, Dr. Compton points out, some 50 million will have died of cancer. The lives of some three million others will have been saved from cancer by the use of x-rays and the radium which was discovered as a result of x-rays. If you add to these the considerably greater number whose lives have been saved by the x-ray diagnosis of tuberculosis, a broken bone or an infected tooth, it becomes evident that even in the warring countries x-rays will have saved as many lives as were taken in battle.

X-rays have also had their great economic and political effects, not so dramatic as those of the war, but perhaps even more far-reaching. What does it mean to the economic and political life of the United States to be integrated by radio? Yet without x-rays, no radio. For the radio is the child of the electron, and the electron owes its recognition to the ionization of the air by x-rays. Similarly, were it not for x-rays we should not now have sound movies or long distance telephony, or radio beacons to guide air mail, or a multitude of other devices that rely upon electrons for their operation.

BASIC RESEARCH IN INDUSTRY

Research is one of the most used, and most abused terms in the English language to-day. Dr. Karl T. Compton, president of Massachusetts Institute of Technology, has defined it—in its simplest terms—as the application of all available knowledge and techniques for the systematic search for new knowledge.

One of the hardest jobs of scientific leaders is to convince industry, at least large portions of it, that research pays in the long run and that new knowledge is the springboard from which is launched future progress of the nation; industrial and otherwise.

One of the commonest short-sighted habits of a company is to apply what is called research to improve existing products, while, at the same time, basic long-range research is neglected.

In a recent address Dr. Compton presents the difference in the two pictures. Suppose a hundred years ago, he said,

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

an industrial laboratory has set out to develop more efficient types of lamps. It would have studied flames, oils, wicks, chimneys and so on. But it almost certainly would not have studied magnets, the properties of metals, electrical currents and high vacuum.

Yet it is out of such studies in pure research that have come modern lighting and communication by wire and radio. The King of England is once said to have asked Michael Faraday of what use were his experiments with compasses, magnets and wire. To which Faraday replied, "Your Majesty, of what use is a baby?"

In many ways applied research, making present things better, is comparable with doctoring a grown man already in, or past, his prime. Fundamental research produces the "new baby," which may turn out to be another genius or intellectual leader; or—to keep the analogy straight—another new and powerful industry.

THE CANADIAN RESEARCH COUNCIL

One of the finest buildings in Ottawa, Canada's capital, houses the Canadian National Research Council, which to the Dominion is what the National Bureau of Standards is to the United States and what the National Physical Laboratory is to England.

It is a "cradle of industry" where new industries are born and nurtured and where old ones are rejuvenated. A company of scientists of all varieties is at work in laboratories within the building, while in various colleges cooperative projects are under way.

Storage and transport of food is being studied as an aid to Canada's commerce. New developments in agriculture are being applied.

Plant hormones that speed growing and may have important practical results are being manufactured and used experimentally. A new kind of barley, with promise of superiority over the original variety, has been produced by heating the seeds and changing their chromosomes. This is the first time that new and valuable economic plant characters have been produced by heat treatment.

To Canada forests are important and acres are being cut daily for paper and other needs. Scientists are looking forward to fast-growing poplar trees to replace the original forests. Canadian cytologists find that natural hybrids between European and native species, with exceptional vigor and some promise of disease resistance, have an extra set of chromosomes, those minute bearers of heredity within the germ cells. They expect to use this fact in breeding rapid growing trees.

Canadian aviation has been aided through the design of airplane skis for use in landing on the winter's snows. All sorts of things from farm windmills to laundry are being investigated in other laboratories.

In many projects that imaginary line between the United States and Canada is obliterated by cooperation between scientists working on the same problem.

RESEARCH ON INFANTILE PARALYSIS

Much research must still be done before infantile paralysis can be brought under control, it appears from deliberations of a group of experts who recently conferred in New York City. In fact, Dr. Thomas M. Rivers, of the Rockefeller Institute for Medical Research, told the group that:

Epidemics of infantile paralysis are caused by a filterable virus. However, all cases occurring in an epidemic of paralysis may not be caused by the same virus. Furthermore, different viruses may be operative in different epidemics.

This means that the muscles must be carefully handled and protected during the very earliest stages of the sickness.

"Skilful protection before wrong positions are assumed and weakened muscles overused or stretched has meant the difference between the resulting disability

and restitution to normal life," a report from the U. S. Public Health Service states.

In order to assist physicians, nurses, physiotherapists and parents in protecting muscles weakened by this ailment and in restoring them by proper exercise to full usefulness, this same government bureau has issued a lengthy bulletin giving detailed instructions on care during the period of recovery from infantile paralysis. One of the points emphasized in this bulletin and by authorities generally is the importance of not starting corrective exercises too soon. Another important point is to avoid the slightest fatigue during exercises.

Infantile paralysis is not expected to become epidemic this summer. It is never safe to make predictions about epidemics, but past experience shows that during epidemic years the number of cases usually increases sharply toward the end of May. With only the normal seasonal increase this year, public health authorities feel that there will be no more than the usual number of cases this fall and summer.

CHANCES OF A CHEMICAL CURE FOR CANCER

THE chances appear good that a chemical cure for cancer will, some day, be found. This hopeful view is justified by a review Dr. Carl Voegtlin, chief of the National Cancer Institute of the U. S. Public Health Service, recently gave of the present status of the chemical attack on cancer.

The future angle must be kept in mind, for so far there is no chemical cure for cancer and no successful method of treating this condition except by surgery, x-rays or radium. However, Dr. Voegtlin says that in the experimental chemical treatment of cancer, when mice, not humans, are the patients, "some suggestive results have been secured." Referring to the way one germ-caused disease after another has fallen under the attack of new chemical remedies, Dr. Voegtlin says "it may not be over-optimistic to look forward to the time when similar results can be achieved in the chemical treatment of neoplasia (cancer)."

Among the results achieved by various researchers, which Dr. Voegtlin believes indicate cancer might yield to chemical attack are the following:

The growth of spontaneous breast cancers in mice was arrested in nearly three fourths of the animals following injections of extract from the placenta or from the skin of embryos. In over one fifth of the animals the tumors actually grew smaller.

An old gout remedy, colchicine, a coal-tar chemical, arrests cell growth and recent research indicates that the growth of certain mouse-cancers can be checked by this drug.

Certain sulfur compounds have been found to have a definite growth-checking effect on breast cancers of mice.

When mice with another kind of cancer are given a substance obtained from one kind of bacteria, hemorrhage and regression of rapidly growing cancers occurs.

LINDBERGH GLASS HEART

Newest triumph of Colonel Charles Lindbergh's "glass heart" apparatus, in supplying oxygen along with the fluid it circulates to organs living outside the body, is accomplished by using blood of what might be termed a living fossil. And blue blood at that.

The creature that supplied the blood is a member of one of the oldest zoological aristocracies on earth, the horseshoe crab. Horseshoe crab shells are familiar to every stroller along the sea beach. They look somewhat like crabs, but are considerably more primitive, and they have a history running back hundreds of millions of years. They may even be ancestral to the rest of us, through a race of sea animals long since extinct, the ostracoderms.

The problem of supplying oxygen through the fluid in the "glass heart"

long had the experimenters stymied. They found they could not use hemoglobin, the red pigment of ordinary vertebrate blood, because it very quickly broke down into a compound that would not carry oxygen, called methemoglobin.

Then, relates Dr. Richard Bing, of Columbia University and the New York Presbyterian Hospital, it was decided to try the blood pigment of the horseshoe crab, a blue stuff known as hemocyanin. A lot of crabs had to be sacrificed to get a sufficient supply, for each crab yielded only about 100 cubic centimeters, or a scant half-teacupful.

The blood itself was not used, but the hemocyanin was extracted and purified through a long series of chemical steps. When it was added to the circulating fluid in the right proportions it worked quite successfully, keeping various mammalian organs like kidneys and thyroid glands alive for several days.

Hemocyanin contrasts oddly with hemoglobin in one respect. Hemoglobin containing oxygen is bright red, and when the oxygen is gone it turns blue. Hemocyanin is blue when oxygenated, and when its oxygen is exhausted it has no color at all.

A NEW SOURCE OF INSECTICIDE

Devil's shoestrings trail along the whole southeastern seaboard of the United States, from New England to Texas. They aren't of any use now, but in time to come a new American industry may start from them. Promise has been counted good enough, at any rate, to justify the spending of considerable research time on the project, by a team of six scientists. The U. S. Department of Agriculture tells what they found in a new technical bulletin.

Devil's shoestring is a plant. It belongs to the pea family, and it is known by such other names as rabbit bean, turkey pea and goat's rue. Botanists call it *Tephrosia*. It looks rather like a vetch, only bigger.

In the tough, woody roots of devil's shoestring chemists have found the same compound now obtained from the roots of derris and cubé, imported in quantities from the East Indies and tropical America, for use in making sprays to kill flies, mosquitoes and other insects. This compound is called rotenone. It is harmless to man and other warm-blooded animals, but deadly to insects; hence its popularity as a spray ingredient.

This discovery of rotenone in the roots of devil's shoestring does not mean that an all-American insecticide industry can be built up overnight. A great deal of pioneering research must still be carried out, paid for either by the government or by private enterprise. Probably the government will be called on to do this preliminary work.

Participants in the research reported in the new bulletin were A. F. Sievers, G. A. Russell, M. S. Lowman, E. D. Fowler and C. O. Erlanson, all of the U. S. Department of Agriculture, and V. A. Little, professor of entomology at the Texas Agricultural and Mechanical College.

DARWIN ON MAN'S MENTAL EVOLUTION

Darwin was not a complete evolutionist. In his famous book, "The Descent of Man," he considered the evolution of man's physical nature only, but neglected the mental and social sides, declares Dr. William E. Ritter, emeritus professor of zoology at the University of California and honorary president of Science Service.

Darwin recognized that these nonphysical aspects of man's life are definitely parts of his nature, and as such must have been as subject to evolutionary influences and resulting changes as his head or his hands or his language. Yet, says Dr. Ritter, "he never tackled the problem in a detailed way. He seems to have regarded it as metaphysics and as such quite unsuited to his special interest and ability as a student."

Dr. Ritter himself refuses to acknowl-

edge a gulf between the so-called physical and metaphysical. In his recent studies he takes the position that "knowing, thinking and understanding are kinds of activity as inseparable from living things as are nutritializing, metabolizing and reproducing."

Dr. Ritter regards as most unfortunate the rather general mode of regarding living things as mechanisms, because the more naive mechanists, at least, unconsciously make it almost impossible to look upon mental and social phenomena as being really parts of human nature. Their explanations either over-simplify them, almost to the point of denying their existence, or they set up a body-versus-mind dualism that is repugnant to sound philosophy.

This way of regarding living organisms as machines was started a couple of centuries ago by Descartes, a French philosopher. Worth noting, in Dr. Ritter's opinion, is the fact that Descartes was not originally a naturalist but a mathematician, therefore having a bias in favor of simple exact descriptions. Darwin, a "natural" naturalist, did much to initiate the modern drift away from the Cartesian mechanistic speculations.

THE INHERITANCE OF RHEUMATIC DISEASE

The idea that rheumatic disease runs in families is pretty old, but it takes on new significance in the light of recent studies by a research team from the children's department of the Johns Hopkins Hospital, the Johns Hopkins School of Hygiene and Public Health and the U. S. Public Health Service.

The figures reported by this group, Drs. Frances E. M. Read, Antonio Ciocco and Helen B. Taussig, show such a strong family tendency to the disease that it suggests a constitutional susceptibility to the condition. If scientists, following this lead, can find definite characteristics of body build or reaction which are associated with rheumatic disease or can learn the order in which cases develop in a family, it might solve some of the unknowns about this disease and even perhaps point the way to control.

The rheumatic condition under discussion is not arthritis, which also used to be called rheumatism, but the kind which appears as St. Vitus' dance, rheumatic fever or rheumatic heart disease. The seriousness of the problem is apparent from the estimate that rheumatic heart disease alone kills between 25,000 and 30,000 persons every year, nearly all of whom are under 30 years of age.

Germ infection is considered by most scientists to be the cause of the condition, but cold climate, dietary lack and poor living quarters have also been strongly implicated. The findings reported by Drs. Read, Ciocco and Taussig to the *American Journal of Hygiene* seem to throw some doubt on the environmental factors.

Rheumatic conditions were found much more often in brothers, sisters and parents of rheumatic patients than in those of non-rheumatic children. But the significant thing is finding rheumatic fever almost three times as often among uncles and aunts of rheumatic patients, and almost eight times as often among their grandparents as among uncles, aunts and grandparents of non-rheumatic children.

FOOD VITAMINS AND FREEZING

With modern canning and cold storage methods there is little or no loss to the vitamin content of foods. In fact in some cases of fruits and vegetables the canned variety may show a higher vitamin content than the usual "fresh" products that the ordinary housewife can buy at the market.

The reason is that, for vitamin C at least, the canned fruits, juices of vegetables are packed quickly at harvest before time permits the oxidation that results in vitamin C losses. The so-called fresh fruits and vegetables, sometimes stored for long periods, gradually lose

their vitamin C content and may be inferior, in this respect, to the canned varieties.

Such, in summary, is the finding of Professor R. Adams Dutcher, of Pennsylvania State College. He cited the following as the human needs for vitamins and the known facts about vitamin preservation:

Vitamin A is needed to aid in preventing infection, for normal vision and normal growth. It is preserved by cold storage. Canned vegetables compare favorably, in vitamin A content, with the fresh variety.

Vitamin B_1 acts as a nerve stimulant. It is not destroyed by low temperature storage.

Vitamin B_2 is required for the proper functioning of the gastro-intestinal tract and the maintenance of a healthy skin. Enough is not yet known about it to give evidence on the effects of canning or cold storage.

Vitamin C prevents scurvy, helps the preservation of normal denture and gives strength and elasticity to the blood vessels of the body. Proper canning and proper refrigeration tend to preserve it.

Vitamin D prevents rickets by aiding the proper utilization of calcium and phosphorus in the bones and teeth. It is very stable and presents no preservation problem.

Vitamin E is the anti-sterility factor in the diet, is quite stable to heat and is easily preserved at ordinary temperatures.

IMPORTANCE OF INTELLECTUAL FREEDOM

More important than the actual discoveries and inventions being made to-day is the preservation of the right to engage in research. For several years the intellectual world has been shocked and disturbed by repeated instances of eminent men of learning forced to leave their work because of intolerance of governments to race, politics, religion or other special view-points.

This has brought forth many protests, among them declarations of the British and American Associations for the Advancement of Science, the Rockefeller Foundation and various codes of ethics and protestations. In England the journal, *Nature*, has editorialized persistently to arouse the scientists to impending danger.

"If science and learning are to regain everywhere the immunity from interference or persecution to which they have been regarded as entitled in all civilized communities for several centuries, it will not be by the efforts of a minority of scientific workers." This is *Nature's* latest editorial warning.

"Science will only be reestablished in its unique place among the interests of mankind when scientific workers everywhere recognize their responsibilities and are prepared to make fresh sacrifices in the cause of intellectual freedom. They must educate their fellow citizens to the realization that science is a common interest of mankind, and that whatever may be the barriers or the difficulties or the struggles between them, civilized societies must accord a certain immunity and tolerance to those engaged in scientific discovery and learning.

"Besides this, there must be a widespread recognition by scientific workers of the normal conditions of tolerance and immunity for scientific pursuits in a civilized state. These restraints—not to meddle with or be dominated by divinity, morals, politics or rhetoric must be clearly understood and firmly accepted by scientific workers. The loyal acceptance of such a code of ethics or discipline is all the more important to-day, not only if objective research in the social sciences is to be pursued, but also if what is often termed the frustration of science is to be overcome."

EXPLORATION BY BALLOON

By Dr. JEAN PICCARD

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THE free balloon was invented in 1783. It was with a great feeling of adventure and only after live animals had been carried into the air and brought safely back to earth that men dared go aloft. As soon, however, as the free balloon was able to stay in the air for hours at a time, attempts were made to use it for exploration. This exploration extended in two directions: vertical and horizontal. First it was the observation of the upper atmosphere which attracted general interest. How high could man go and still live? How did the air differ from the air at the ground? What would the temperature be at great altitudes?

In the second half of the last century, when photography became possible under more general conditions the free balloon was extensively used for taking photographs from places which could not possibly be reached by any other means of transportation. It was at this time that "Captain" Spelterini brought down most remarkable pictures from the Alps. With a skill attained by few others, if by any, he could pilot his large balloon close to the Swiss glaciers and take most beautiful photographs. He was the first man who flew over the Alps and he was also the first man ever to fly over the Egyptian Pyramids and over the Sahara Desert.

At about the same time the Swedish explorer Andrée started his ill-fated expedition across the north polar wastes. He succeeded indeed in exploring unknown territory but, unfortunately, his balloon could not stay in the air as long as the bold aeronaut had anticipated. Andrée and his two companions died on their return trip by foot, and the results of their great flight were brought back to civilization only long after the tragic death of the three explorers.

During the first hundred years after its invention the free balloon had made the atmosphere well known to mankind and the possibility of navigating it by means of the dirigible balloon and later by means of the airplane might still remain a dream, had not the free balloon first shown the way.

In the years just prior to the world war several free balloon flights were made in order to check on phenomena like adiabatic compression, diffusion of gases, absorption and loss of heat. These flights, although not producing scientific results of revolutionary importance, showed, nevertheless, that the gondola of the free balloon could be transformed into a physical laboratory of great efficiency.

The free balloon, at this time, could not go very high, and for the exploration of greater altitudes one had to rely entirely on the pilot balloon and the sounding balloon. Both of these instruments are unmanned. The first one, the pilot balloon, does not even carry apparatus. It is observed by means of a telescope or a theodolite, and the only results it can give to the observer are speed and direction of wind at various heights. The second one, the sounding balloon, is a much improved instrument of meteorology. It carries various apparatus which automatically register their findings, usually on a revolving drum, so that the results may be read by the sender once the balloon has been recovered.

The discovery of the stratosphere by Teisserenc de Bort is entirely due to these sounding balloons. It was well

known from previous flights that the higher one goes the colder the air gets. The decrease is about one degree Fahrenheit for each three hundred feet. This is what is called the temperature gradient. To his great surprise the French scientist discovered that when a certain low temperature was reached no further cooling took place at still greater altitudes. (The theory explaining why there should be such a phenomenon was later given by Humphrey, of the U. S. Weather Bureau in Washington, and by E. Gold.) From his findings Teisserenc de Bort concluded, a little too hastily, that above a certain limit, about seven to eight miles high, the air was *completely* stratified. No vertical currents *at all* would take place there. This region was called the isothermal layer or the stratosphere.

This was the time when it was generally assumed that in the absence of any mixing of the air at great altitudes the various gases of the atmosphere would separate according to their densities. Some text-books of this period contain the amazing statement that the stratosphere consists mostly of hydrogen.

Fortunately, the same sounding balloons which had told us about the existence of the stratosphere were also able to bring down specimens of air which were then analyzed in the chemical laboratories. These analyses showed that the air from as high up as samples could be obtained had very nearly the same composition as it had at sea level. The truth is that the stratosphere, as first conceived by Teisserenc de Bort, does not exist. Small disturbances exist everywhere, even in the stratosphere.[1]

The only information about winds which we have from heights above the ceiling of the highest balloon has occasionally been obtained by observation of the tails of large meteorites. These observations also show that there is in the air no place of perfect calm. We know of no region in the atmosphere, high or low, where some mixing does not take place, and this mixing is always more important than the separation (by gravity) of the constituents of the atmosphere.

A substantial prize offered some thirty years ago by the New York sport enthusiast, James Gordon Bennett, did more than any other single factor to promote free ballooning all over the world. The great International Air Races and the training connected with them were for years the grandest thing one could see in sports. Unfortunately, they had to be interrupted during the world war. After the war, there were several reasons why free ballooning never attained its former popularity. It is true that the Gordon Bennett air races were resumed, and several active balloon clubs were developed, but never did free ballooning as a sport become what it had been.

One of the reasons was, of course, the ever-increasing success of the airplane. Not only did the latter promise to become of greater military and commercial importance, but the distance record and even the altitude record were taken away from the balloon. Only the uninteresting endurance record was not beaten by the airplane.

At this time, however, and very fortunately, the free balloon was again used for explorations of various kinds. The German airplane builders wanted to know exactly how the gasoline engine would behave at great altitues and in order not to complicate their investigation by the introduction of several unknowns at the same time, they carried their engine up in a free balloon, the men using oxygen masks for breathing.

The famous Michelson-Morley experiment was repeated in a free balloon by

[1] During his second stratosphere flight (1932), Auguste Piccard had a silk flag hanging 150 feet below the gondola. This flag was in motion during the whole flight, even when the barometer showed no variation of altitude and the balloon itself seemed to float in perfect tranquility.

Auguste Piccard. This Michelson-Morley experiment is among the most difficult experiments ever performed in a physical laboratory. The whole relativity theory depends on it and yet doubts had been expressed in some quarters about its findings. It was stated, specifically, that the results of Michelson and Morley would have been different if these two scientists had not confined their work to a laboratory built under ground but if they had placed their apparatus a few feet above the earth's surface. Auguste Piccard demonstrated that under the conditions under which he worked, *i.e.*, in a free balloon at 10,000 feet, the old findings were correct: the wave-length of light was independent of the direction of the light. This means, expressed in a more popular form, that there is no "ether drift." Auguste Piccard showed that it is not only possible to repeat the experiment in the limited laboratory built within the gondola of a free balloon, but that it is far easier in a free balloon to eliminate all possibility of error from outside influences. Instead of rotating the apparatus inside of the laboratory, he rotated everything, apparatus, laboratory, gondola and balloon. The measurements were made at night, of course, and there remained no outside influence which could act differently from different directions. The balloon, moved by two electric motors with two propellers, made 150 rotations per hour. All measurements were recorded on photographic films and the final readings were made later in the laboratory. This experiment demonstrated, once more, that the possibilities of the free balloon as an instrument for physical exploration were far from exhausted.

This kind of experiment could never have been made in an airplane. It needed the steady rotation around a vertical axis of utmost stability. There is, indeed, no better bearing than the spherical balloon floating freely in the tranquil air of the night, high above the cities, towns and country.

At about the same time, some twelve years ago, one nation after another adopted a new method for meteorological forecasts, the so-called Norwegian air-mass analysis method. The older, *i.e.*, the classical, method tried to forecast the weather by observing the weather map on which the isobars were drawn. The determination of these isobars or lines of equal barometric pressure was the result exclusively of observations made on the ground. The well-known unreliability of these older forecasts was taken as a necessary evil. The new method, however, is based on the understanding that the weather is not only the result of conditions prevailing on the surface of the earth, but that the weather forecaster must be given a complete description of conditions throughout the atmosphere, at high as well as at low altitudes. Furthermore, not only the pressure but also the temperature and the humidity of the whole air mass must be known. The amazing results of the air mass analysis method could not fail to make it be adopted by all weather bureaus. This gave, of course, a tremendous impetus to the development of sounding balloons. The sounding balloon is the instrument *par excellence* to inform us daily about temperature and moisture in the upper atmosphere.

The ordinary sounding balloon is made from pure rubber. It is closed, and while it rises, the hydrogen in it expands. The ascensional force remains constant during the whole flight. While the balloon gets bigger and bigger, it passes through air layers of lower and lower density. Therefore, while the balloon gets larger its resistance per square foot diminishes and, as a result of these two factors changing in opposite direction, the speed of the balloon remains practically constant during the whole ascent. There always comes a moment when the balloon can not expand any further with-

out exceeding its limit of elasticity. Then the balloon explodes invariably, and the instruments, attached to a parachute or to a second balloon not large enough to support them entirely, reach the ground safely.

It is not necessary for air mass analysis to have the sounding balloons remain at their ceiling over a long period of time, and, indeed, the rubber sounding balloon could not be made, without considerable transformation, to remain at its top altitude for any length of time.

The sounding balloon has also been used for other purposes than for meteorological work: Millikan in California and Regener in Germany used it to carry cosmic ray apparatus to heights never reached by man. In this field, however, the results which the sounding balloon may collect are very incomplete, and at the same time as Millikan and Regener perfected their methods of investigation, Auguste Piccard took once more to the free balloon for exploration. His aim was to reach a region where he would have nine tenths of the air below him and only one tenth above. There, of course, the atmospheric pressure is exactly one tenth of what it is here. The barometer, instead of standing at thirty inches as it does at sea level, shows only three inches of pressure. These conditions are reached at an altitude of about ten miles.

It was clear that no human being could live and observe at this reduced pressure even when breathing pure oxygen. Therefore a new gondola had to be designed. It was spherical and hermetically sealed. The air contained in such a gondola of seven feet diameter was sufficient to keep two men alive for a few hours only. For this reason, a complete air regeneration apparatus was put in the gondola. The temperature regulation was made by choosing proper painting inside and outside. The gain of heat by radiation from the sun is terrific, but the loss of heat by convection is also very great. In his first flight, Auguste Piccard suffered from heat. The inside temperature went up to + 104° Fahrenheit. During the second flight he suffered from the cold. The inside temperature went down to + 10° Fahrenheit. From these experiences he could, however, design a gondola which was bound to have a convenient temperature throughout the flight.

By using the system proposed by him, Mrs. Jean Piccard and the author in their flight from Ford Airport in Dearborn, Michigan, observed in the inside of their gondola a temperature slowly rising from + 55° on the ground in the early morning to + 67° F. at noon in the stratosphere, where the outside temperature was – 67° F. This was accomplished not by any complicated machinery but by the simple device of having a heat-absorbing black paint on the lower part of the gondola and by having the top painted white with a heat-reflecting paint. The dividing line between the two paints was six inches above the "equator" of the gondola. The inside of the gondola was entirely white. From now on no one in a stratosphere gondola needs to suffer any more from heat or cold at day-time.

The new gondola was, however, not the only alteration needed to transform the old free balloon into the stratosphere balloon. The design of the bag, the ropes, etc., and the method of inflation were very probably the more difficult part of the invention. A complete description of these problems as well as any detailed discussion of the gondola lies beyond the scope of this article. We must be content with merely mentioning them.[2]

Auguste Piccard and his associates were able to make three flights with their original balloon (1931, 1932 and 1934). More flights were made with similar but larger stratosphere balloons from Russia and the United States. The most important of these flights was the National

[2] Detailed description may be found in Auguste Piccard's book, "Auf 16,000 Meter," published by Schweizer Aero Revue, Ag, Zurich.

Geographic Society—U. S. Army flight of Stevens and Anderson (1935). While most of the other flights had as sole or main objective the investigation of cosmic rays at great altitudes, the last-named flight included many other investigations in its program (photography, spectroscopy, collections of air specimens, etc.). For this flight, as well as for the already mentioned flight of Mrs. Piccard and the author, most of the cosmic ray apparatus were designed by W. F. G. Swann and his collaborators at the Bartol Research Foundation of the Franklin Institute, Swarthmore, Pa.

Among the various alterations and improvements of the stratosphere balloon, subsequent to the first flight by Auguste Piccard, two or three must be mentioned: first the construction of a valveless balloon by Max Cosyns, the assistant of Auguste Piccard. This system allows the pilot to release gas through a tube hanging down from the zenith of the balloon. This tube is always open. By changing the position of its lower end one releases the gas below any desired point in the axis of the balloon. This allows perfect stability at any altitude. Secondly, let us mention a valve, controlled not by a rope but by compressed oxygen. We owe this invention to Stevens. And finally, let us mention the use by the author of electric blasting caps for the instantaneous release of ballast. This method, which was much improved by Cosyns, makes it possible to keep the bulk of the needed ballast outside of the gondola and relieves the pilot from the work of handling this heavy material. These and other inventions have greatly added to the safety of the stratosphere balloon and to the tranquility of its occupants.

Photographed by Jean Piccard.

A GORDON BENNETT RACING BALLOON AT THE START FROM CHICAGO, 1933.

On these stratosphere flights since 1931 heavy and complicated cosmic ray apparatus were used. On one of the American flights, one of the apparatus alone weighed 600 pounds. On this same flight the balloon was successfully and constantly rotated while in the stratosphere. This allowed the observation of the east-west effect of cosmic rays, an effect in which physicists are greatly interested.

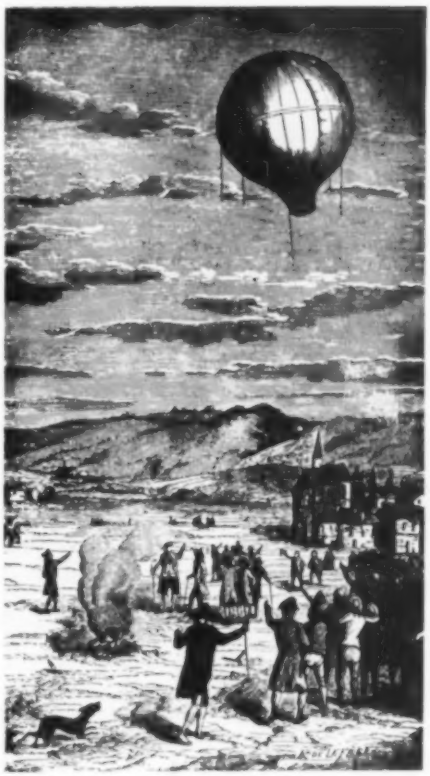
While these stratosphere flights, when properly prepared, are exceedingly safe for the explorers, they have the great inconvenience of also being exceedingly expensive. This is the main reason why, parallel with these flights, sounding balloon flights for cosmic ray investigation are still made. No sounding balloon can ever bring down results comparable with the results gained by a manned stratosphere balloon, but for the same money as needed for one "big flight" many sounding balloons can be released and the accumulated results of these many "little flights" will eventually be quite important. There is no real competition between the two methods of research. Each has its advantages, and each can bring down results which the other could not be expected to yield.

Modern meteorology is not satisfied with the old sounding balloon which automatically records its findings. Usually days, sometimes weeks or months pass before the balloon is recovered, if at all.

At best, it takes many hours before the balloon is found and the instruments read. The results, although scientifically of great value, can rarely be used for any weather forecast. Meteorology is therefore greatly interested in the radio balloon. This is a sounding balloon which does not record the reading of its instruments. It sends the results down immediately by radio. The readings are thus available in the laboratory minute for minute while the balloon is going up. In the meeting of the American Meteorological Society in Kansas City, Lange, of Harvard University, demonstrated the new system at the airport. As soon as the balloon had left the ground, the apparatus in the hangar began recording automatically the pressure (*i.e.*, altitude) and the corresponding temperature and humidity. All these data were therefore immediately available to the air mass analyst for his weather forecast.

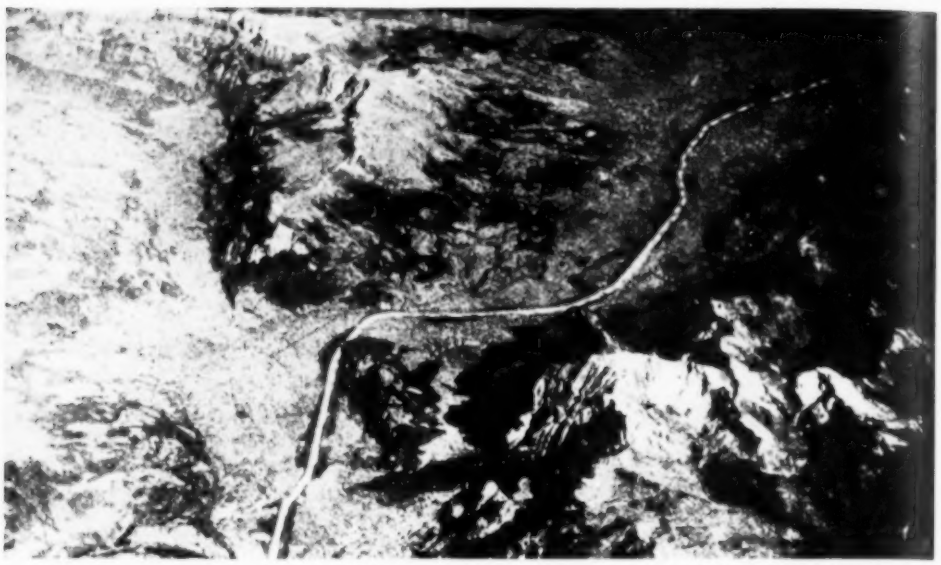
Physicists have also started the use of the radio balloon for cosmic ray investigation. The results are still very fragmentary, but they are certainly very encouraging. Since for cosmic ray investigation we need a longer time of observation, T. H. Johnson and the author used sounding balloons made from Cellophane. The Cellophane is not elastic, and the balloon can be built with an open appendix like a manned balloon. With a rubber balloon this is not possible, since rubber always has a tendency to contract and to expel the gas unless the balloon is carefully sealed. The sealed balloon, as we have seen, always rises till it explodes.

The new Cellophane balloon looks very much like a manned stratosphere balloon. It is partially inflated and pear-shaped at the start. When it reaches its ceiling, gas escapes through the open appendix and a position of equilibrium is maintained. This condition of equilibrium is further improved by an automatic ballast apparatus which releases sand as soon as the balloon has a tendency to go down. After a predetermined number of hours, a small rip panel is opened which, automatically, starts the balloon on its return trip to earth. In this manner one can make sure that the ballon will land during the day-time. Two results are secured by this procedure: First, the balloon does not endanger airplanes by crossing their paths during the night, and secondly, the chances of recovery are considerably improved if the balloon is visible before landing.



THE START OF THE FIRST MONTGOLFIÈRE
ANNONAY, FRANCE, JUNE 5TH, 1783
REPRODUCTION OF AN ENGRAVING MADE IN 1783.
FROM BOOK "AUF 16,000 METER" BY AUGUSTE
PICCARD, PUBLISHED BY SCHWEIZER AERO REVUE,
ZURICH, SWITZERLAND.

These Cellophane balloons are, of course, heavier than rubber balloons. They will not reach the greatest altitudes, but they will carry heavy loads to the base of the stratosphere, and they will travel horizontally at great distances and in this manner will give a true picture of



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PHOTOGRAPH TAKEN BY AUGUSTE PICCARD FROM THE STRATOSPHERE ABOVE THE SWISS ALPS. ALTITUDE OF BALLOON 16,200 METERS. TO THE RIGHT: THE MOUNT FALKNIS. IN THE MIDDLE THE RHEIN RIVER WITH SAND BANKS ALTERNATINGLY TO THE RIGHT AND TO THE LEFT OF THE STREAM. IN THE LEFT UPPER CORNER THE WALENSEE (LAKE WALEN). THE PICTURE IS TAKEN LOOKING STRAIGHT NORTH. FROM BOOK "AUF 16,000 METER" BY AUGUSTE PICCARD, PUBLISHED BY SCHWEIZER AERO REVUE, ZURICH, SWITZERLAND.

the air mass movement. A Cellophane balloon of this kind (fifteen feet in diameter) was released in June, 1936, from Minneapolis by the Department of Aeronautical Engineering of the University of Minnesota. It traveled to Arkansas and landed 613 miles from its starting point. The Cellophane balloon has its place beside the rubber balloon. While rubber balloons can only be made in the factory, every one can make his own Cellophane balloon as large or as small as he wants it. The toughness of Cellophane is such that, making the balloon a little larger than ours, it would allow its use by man.

The use of non-elastic Cellophane balloons for sounding balloons was, exactly speaking, an adaptation of the free balloon technique to the purpose of exploration by unmanned balloons. It is interesting to note that the reverse can also be done. We can indeed use the sealed rubber balloons to lift man himself into the stratosphere. By doing this we give up certain advantages of the open-neck free balloon, but we make use of other advantages offered by the rubber sounding balloon. The main advantages of this proposition are the low cost of an expedition and the great height which can be reached. Since single sounding balloons can not be built large enough to lift a gondola containing human beings, a cluster of these sounding balloons must replace the single bag. This introduces a new and most welcome condition for the pilot and the crew: a considerable increase of the safety factor. A single rubber balloon might burst at any moment, but the probability that out of three or four thousand balloons a considerable number would explode at the same moment is, statistically speaking, zero.

It is easy to demonstrate mathematically that the ratio of strength to weight is far more advantageous for the sounding balloon than for the open-neck free balloon, and the dangers of a failure at the start are considerably smaller. It

must be conceded, however, that a manned stratosphere flight with sounding balloons is so much at variance with the use of the orthodox free balloon that even if all the details can be calculated to the entire satisfaction of the engineer there still remains for the pilot an element of doubt which can only be overcome by experience with the new device. In other words, the new type of aerostat should first be tested under most favorable conditions. For this reason the Kiwanis Club of Rochester, Minn., sponsored such a test flight by the author. In order that the pilot could keep greater liberty of action in the case of unforeseen incidents it was decided to use an open basket and to remain below the limit where breathing atmospheric air might become difficult. The author decided also that his trusted pilot, Mrs. Piccard, should remain on the ground and concentrate her activities on the organization and command of the ground crew. The flight itself could easily be made by the author alone. The flight of the "Pleiades," as the aerostat was called, took place on July 18, 1937, and gave the desired proof of the navigability of the new aircraft. At the start the "Pleiades" consisted of two clusters of about 46 Dewey and Almy balloons each. For the descent and for the landing about 15 balloons were either released, stabbed or shot and after the landing the whole upper cluster was freed by the detonation of a T.N.T. fuse.

The Future

We have now at our disposal a large variety of instruments for the exploration of the atmosphere and especially of the stratosphere. We do not know if any of these instruments will ever be able to supplant the others. It is possible but not likely. For a long time to come the exploration of the stratosphere will go on and all available methods will be used. The investigation of the cosmic rays is of prime importance to science. There is in the universe as a whole probably as much energy in cosmic rays as there is in heat rays and in light. Since cosmic rays come to us from the empty interstellar space or from faraway stars, the most significant results are obtained if the cosmic rays are studied at the place where they enter our atmosphere, the place where they are the most nearly in their original state.

A wealth of information, useful to all natural science, has already been brought down from the stratosphere, but the more we get, the more we want, and much more information is still there, ready to be brought down from the region where our planet and empty space meet.

But quite apart from the purely scientific interest in the upper air there is also, from a business point of view, an important reason why we must know more about the stratosphere. The commercial airplane, the most perfect instrument of peaceful intercourse between the peoples of the world, must fly high in order to fly safe. High above the clouds, in the eternal peace of the serene stratosphere, lie the high roads for future long distance communications. There is no bumpy air in the stratosphere, no rain or snow, no mountains to hit in the fog, and the deadliest of all enemies of the plane, the dreaded icing conditions, are absent every day of the year.

How high will man go eventually? Calculation shows that the airplane is not likely to go much above ten miles. The great stratosphere balloon, however, with its sealed gondola, is still far from having exhausted its possibilities. Auguste Piccard has an entirely new design for a large stratosphere balloon which is calculated to go to an altitude where the barometric pressure is only one hundredth of an atmosphere, 0.3 inches of mercury. This condition will be reached a little below twenty miles. This is also, approximately, the ceiling of the "Pleiades" type of aircraft. Above twenty miles stratosphere flying for humans will begin to be not only difficult but dangerous.

WILLIAM WALLACE CAMPBELL

FORMERLY DIRECTOR OF THE LICK OBSERVATORY AND PRESIDENT OF THE UNIVERSITY OF CALIFORNIA.

THE PROGRESS OF SCIENCE

WILLIAM WALLACE CAMPBELL

WILLIAM WALLACE CAMPBELL, one of the great figures in America's university and scientific work, departed this life on June 14, 1938. One of his colleagues, Dr. R. G. Aitken, has written an appreciation of Dr. Campbell's life and work for a recent number of *Science*. A biography is to appear in due course from the National Academy of Sciences, and other tributes have been and will be paid to the services of our distinguished fellow citizen. The writer can not speak with authority of Dr. Campbell's work in astronomy, but can in his humble way say a few words in profound appreciation of his life and its significance to his country and his fellow citizens.

At the time of his death President Campbell had passed his seventy-sixth birthday. In that period of about three quarters of a century he attained with remarkable versatility achievements of first rank in teaching, in research and administration in one of the world's great observatories, and in the administration of one of America's great universities. Born in Ohio and a graduate of the University of Michigan, he passed in turn from a professorship of mathematics and practical astronomy through the positions of astronomer, director of the Lick Observatory and president of the University of California. He was in active service as the director of the Lick Observatory for a quarter of a century and in the presidency of the University of California for seven years. In the year 1915 he was president of the American Association for the Advancement of Science, and in the period 1931–35 he was president of the National Academy of Sciences. His honors, both at home and abroad, were many and distinguished. But these brief statements of fact signify merely his versatility and imply valuable service. They do not give us light on the really significant features of his labors and his contributions to America's progress. The really meaningful appraisal of Campbell's life and work can not omit reference to his magnificent character, to his unfaltering loyalty to the best standards of living and working which our halting civilization has thus far produced. As a result of many years of close friendship and official association, I can say that I have never known a man who was more genuine, more considerate, more helpful and more devoted to high standards of living and of working. His was a great spirit attuned to the eternal verities. He despised sham and silly pretense and never compromised with his conscience. This brought him at times much grief and pain, for our practical world is harsh, but he always stood by his guns.

Impressive accounts of Campbell's achievements have already appeared in the European press as well as in the American press. They pay tribute to his distinguished researches in astronomy, to his masterly conduct of eclipse expeditions, to his long and successful direction of the Lick Observatory and to the high standards by which he administered the teaching and research of the University of California. In the writer's opinion, however, the greatest of his services, and they have all been great, is the example of character, rectitude of purpose and action, unfaltering devotion to family, to country and decent standards of civilization, which he set for us.

He died as he lived—with lofty courage and with the thought of others taking precedence in his mind over thought for himself. We mourn his passing but rejoice with his family in the grand legacy which he has bequeathed to us.

CHAS. B. LIPMAN
DEAN OF THE GRADUATE DIVISION
OF THE UNIVERSITY OF CALIFORNIA

PROFESSOR CHARLES FREEMAN WILLIAMS McCLURE

PRESENTATION TO PRINCETON UNIVERSITY OF PORTRAITS OF PROFESSOR EDWIN G. CONKLIN AND PROFESSOR CHARLES F. W. McCLURE

On the afternoon of Baccalaureate Sunday, June 19, 1938, portraits of Dr. Edwin Grant Conklin, Henry Fairfield Osborn professor of biology, emeritus, and of Dr. Charles Freeman Williams McClure, Class of 1877 professor of zoology, emeritus, were presented to Princeton University. The occasion marked the fiftieth anniversary of Professor McClure's graduation from Princeton and the thirteenth anniversary of Professor Conklin's association with Princeton. The portrait of Professor Conklin was a gift to the university from many of his colleagues, former students and friends. Dr. McClure's portrait was the gift of members of the Princeton Class of 1888, colleagues, former students and friends. The two portraits, which are the work of Mr. John Young-Hunter, have been hung in the main hallway of the Biological Laboratories in Guyot Hall.

Dr. Livingston Farrand, formerly president of Cornell University and a graduate of Princeton in the Class of 1888, represented the donors in presenting the portrait of his classmate, Dr. McClure, to the university. In part Dr. Farrand spoke as follows:

> This is not the time or place, nor am I competent to review in detail Dr. McClure's professional career and his contributions to biological science. It happens that I have been in a position to know something of his work in studying the development and comparative anatomy of the lymphatic system and the monographs and papers by himself and Huntington stand as classics in that region of biology. They exhibit that meticulous accuracy of observation and adherence to fact which have always characterized his work, and they form the basis of his later studies on the development of the vascular system, which field he has made peculiarly his own.
>
> It is, however, another side of Dr. McClure's career at Princeton that I would emphasize. Something more than learning and mastery of fact is needed to make the great teacher. Certainly a fundamental aim of education is to arouse and establish in the student the spirit and habit of inquiry, and that Dr. McClure has accomplished in notable degree. Successive generations of Princetonians have been his beneficiaries.
>
> And these rare qualities have been enriched by that straightforward, lovable personality that we, his friends of more than fifty years, know so well. His interest in others has always been genuine and constant, and hundreds of men of standing and influence in their communities look back with gratitude to what they gained from his teaching and friendship in their years as undergraduates on this campus.

Dr. George Packer Berry, a former student of Professor Conklin and a graduate of Princeton in the Class of 1921, represented the donors in presenting Dr. Conklin's portrait to the university. A portion of Professor Berry's address was as follows:

> It is more than an honor and a privilege, it is a genuine pleasure, to present to Princeton University, on behalf of his many students, colleagues and friends, this portrait of Professor Edwin Grant Conklin.
>
> How peculiarly fitting it is that a likeness of Dr. Conklin is to find a permanent place in Guyot Hall. For almost thirty years this has been the scene of his labors. Here he has built a renowned department. Here, as an incentive for all, his portrait will personify his ideals.
>
> Dr. Conklin's investigations on cell lineage and the mechanisms of reproduction are classics and have had a tremendous influence on the development of embryology. His studies, characterized by extraordinary accuracy and insight, and presented with clarity and unusual artistry, have contributed enduring pages to the literature of science.
>
> The philosophical implications of biological discoveries and theories for human affairs have always concerned Dr. Conklin. Nowhere has he expressed this interest more forcibly than in the far-sighted paper, "Science and Ethics," which he read last December as retiring president of the American Association for the Advancement of Science. By his extensive writing, even more perhaps by his addresses, he has brought the work of the scientist authoritatively before the public.
>
> As a teacher, also, Dr. Conklin has attained great distinction. The stimulus which he has

PROFESSOR EDWIN GRANT CONKLIN

given to the students who have come under his spell is an immeasurable contribution to science. Indeed, there is no one in the whole group of biologists so widely known and so influential as he. His persistent idealism, his earnestness as a lecturer and his clarity of exposition have led many to share his enthusiasm for the study of living things.

In many respects, his course, "General Biology 201, 202," became the most significant one on the campus. It was frequently voted "most popular" by the undergraduates. His book, "Heredity and Environment," gave many a more penetrating insight into life. To-day, undergraduate and graduate students alike come in increasing numbers to Guyot. To how many of them has Dr. Conklin lent his ever-ready ear! The artist, Mr. John Young-Hunter, is to be congratulated for having appreciated in him this generous trait, this willingness to listen, and for having portrayed Dr. Conklin in what is to me one of his most characteristic attitudes, that of the sympathetic listener.

As a counselor, Dr. Conklin's mature advice has been sought far and wide. Since the beginning he has been a leader in the organization and conduct of the Marine Biological Laboratory at Woods Hole. His dominant influence in the American Philosophical Society has brought to that ancient and honorable body a new prestige. He has been president of most of the biological organizations to which he belongs. To each he has given devotedly of his time and energy. His seasoned judgment of men and affairs has profited greatly the scientific groups which he has served.

What of Dr. Conklin as a man? Little need to refer to this at Princeton! To know him is to love him. That says all. Investigator, teacher, administrator, counselor, human being—who shall say in which capacity his attainments are highest? In all directions his eminence is recognized. He has steadfastly adhered to the guiding principle of his life: "And ye shall know the truth, and the truth shall make you free."

In accepting the portraits on behalf of Princeton University, President Harold Willis Dodds said:

I am happy to accept in the name of the university these portraits of Professor Conklin and Professor McClure, the gifts of grateful students and co-workers of the past who by this method acknowledge their indebtedness to two great teachers. Others are better qualified than I to speak of their contributions to science. I want briefly to refer to them as personalities.

Professor Conklin's scientific attainments alone have earned him merited fame, but his career has also been important for other than his gifts as a scientist. Eminent as a pioneer on the frontier of scientific discovery, he has never been satisfied with any narrow definition of his vocation. Rather has his life emphasized the integral relation among science, philosophy and human welfare. Throughout the years in which academic influences were constantly pressing for greater and greater specialization, Professor Conklin kept insisting that science must be conceived in terms of human welfare and that the results of science must be articulated to human problems. Nothing that he has said represents this breadth of outlook better than his recent speech as retiring president before the American Association for the Advancement of Science. For myself, I herewith confess publicly my debt to the impress of Professor Conklin's thinking upon mine. His position in the world of thought is unique. May he live long to continue his remarkable influence.

The work of Professor McClure likewise can not be measured by his contribution to science in the accepted sense. For more than forty years following his graduation in 1888 he has been a loyal and effective member of our faculty, bringing to it welcome distinction. The results of his work can not be expressed alone by concrete additions to scientific knowledge. To me his great contribution has been the inspiration of his teaching, kindling in his students the flame of enthusiasm for science and leading them after graduation to continue the pursuit of knowledge in all the broad domain of science. In hundreds of students he has inculcated the discipline of science and respect for it. Literally hundreds of practicing physicians, for example, are to-day better scientists and therefore better physicians for having worked with him. To Professor McClure has been given the true reward of the gifted teacher, the assurance that he has transmitted his vision in ever widening circles to younger men equipped to carry forward the search for truth in years to come. As he retires from active service his colleagues extend affectionate regards and the hope that he may enjoy many years of health and happiness.

The world has need of scientists and teachers who exert positive influences molding forever the lives of their students. This high capacity is revealed in the two we honor to-day, and the university is proud to have been the instrumentality through which they have impressed themselves upon the lives of those who, desirous that the memory of two beloved teachers be perpetuated here, have given us these beautiful portraits. To the donors and to the artist who has worked with such understanding we extend our thanks for these expressions in oil of two great personalities.

ELMER G. BUTLER
CHAIRMAN OF THE DEPARTMENT OF BIOLOGY, PRINCETON UNIVERSITY

—Photo from Wide World Photos.

LORD RAYLEIGH

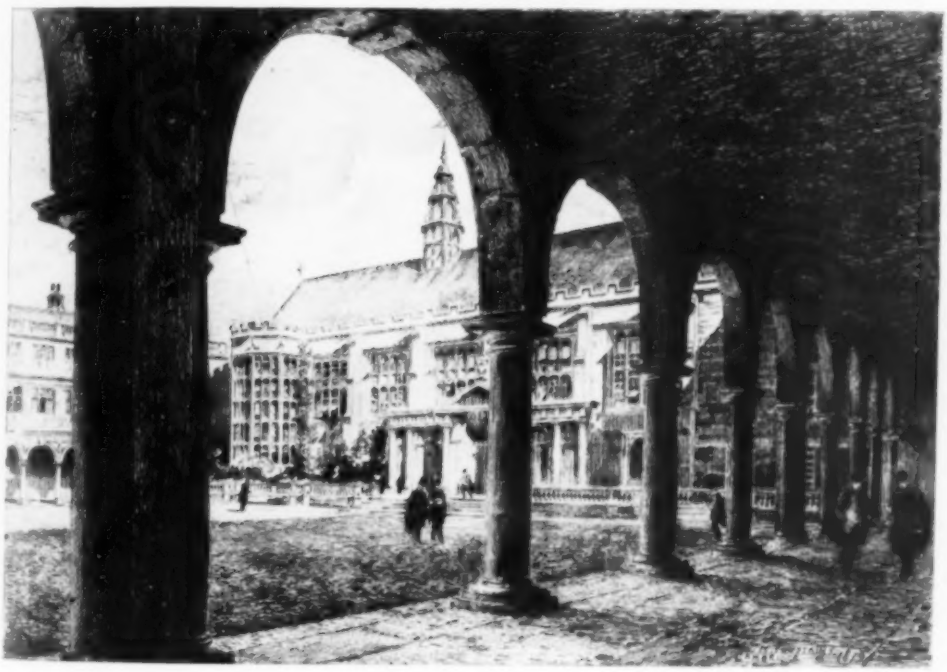
PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE CAMBRIDGE MEETING OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE British Association for the Advancement of Science held its annual meeting this year in Cambridge, from August 17 to 24. This is the fifth meeting of the association to convene in Cambridge and the second in the present century. Cambridge first received the British Association at its third meeting, held in 1833 under the presidency of the Rev. Professor Adam Sedgwick. The association met again in Cambridge in 1845, when Sir John Herschel was president, and has since convened in 1862 under the presidency of the Rev. Professor Willis, and in 1904, when the Rt. Hon. A. J. Balfour presided.

This year's president of the association is the Rt. Hon. Lord Rayleigh. He was president of the section of mathematics and physics in 1929 and president of the Physical Society 1934–36. His father, also a distinguished physicist, was president of the association when it met in Montreal in 1884.

According to the preliminary program, the inaugural general meeting of the association was to be held on the evening of Wednesday, August 17, in the Regal Cinema, when Lord Rayleigh was expected to deliver the presidential address on "Natural Vision and Vision Aided by Science." The address dealt with observational methods in modern science, pointing out their ultimate derivation from features of the structure of the human eye, and with the relation-



Etching by H. Toussaint

NEVILLE'S COURT, TRINITY COLLEGE

SIR JOSEPH THOMSON, FORMERLY CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS, IS MASTER OF TRINITY COLLEGE. LORD RAYLEIGH, THIS YEAR PRESIDENT OF THE BRITISH ASSOCIATION, WAS A STUDENT OF THE COLLEGE, AS WAS HIS FATHER, THE LATE LORD RAYLEIGH, WHO PRECEDED SIR JOSEPH THOMSON AS CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS. HE WAS PRESIDENT OF THE BRITISH ASSOCIATION IN 1884.

Etching by H. Toussaint

ST. JOHN'S COLLEGE

ships between science as a whole and modern warfare. Two evening discourses to members were to be given in the Arts Theater, the first on the evening of August 19 by Dr. H. Godwin, on "The History of the Fens," and the second on "The Contribution of the Electrical Engineer to Modern Physics," by Professor M. L. Oliphant on the following Monday evening, August 22.

The sectional meetings of the association began on Thursday, August 18, and continued daily, except Saturday, until August 24. Presidential addresses in the sections included a discussion on "Recent Investigations in the Chemistry of Gold," by Professor C. S. Gibson (Chemistry), "The Future Development of Oceanography," by Dr. S. W. Kemp (Zoology), "Correlations and Culture, a Study of Technique," by Professor T. Griffith Taylor (Geography), "The "Changing Outlook of Engineering Science," by Professor R. V. Southwell (Engineering), "The General Physiology of the Plant Cell and its Importance for Pure and Applied Biology," by Professor W. Stiles (Botany), and "The Proper Function of Administration in Public Education," by J. Sargent (Education). Sectional transactions embrace a very wide range of subjects, including recent developments in nuclear physics, the organic chemistry of metals, postglacial history of the fens, soil conservation, cosmic ray research, problems in education and society, road and air transport, problems of modern engineering, low temperature research and many others.

CARYL P. HASKINS